627

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 MARCH 1952

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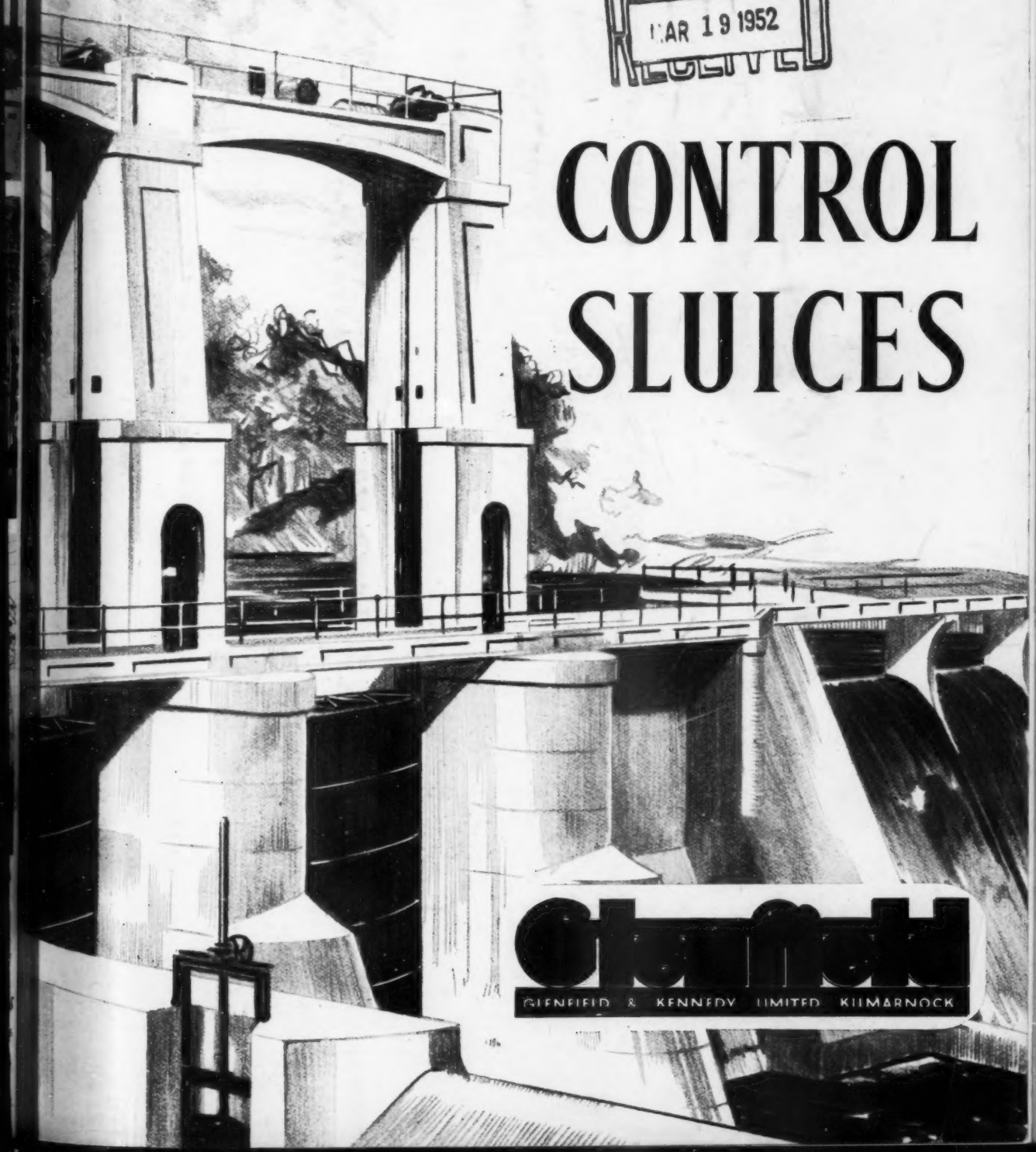


CONTROL SLUICES

Glenfield
GLENFIELD & KENNEDY LIMITED KILMARNOCK

METALCLAD SWITCHGEAR AT ABBEY STEEL WORKS

Reyrolle Metalclad horizontal draw-out switchgear was selected for the main control of supplies within the Abbey Steel Works, Port Talbot, South Wales. The 11 kV switchboards are of various ratings, these being type B5T with oil-break circuit-breakers of 500 MVA breaking capacity and types B3T and B2T switchgear of 350 MVA and 250 MVA breaking capacity respectively.

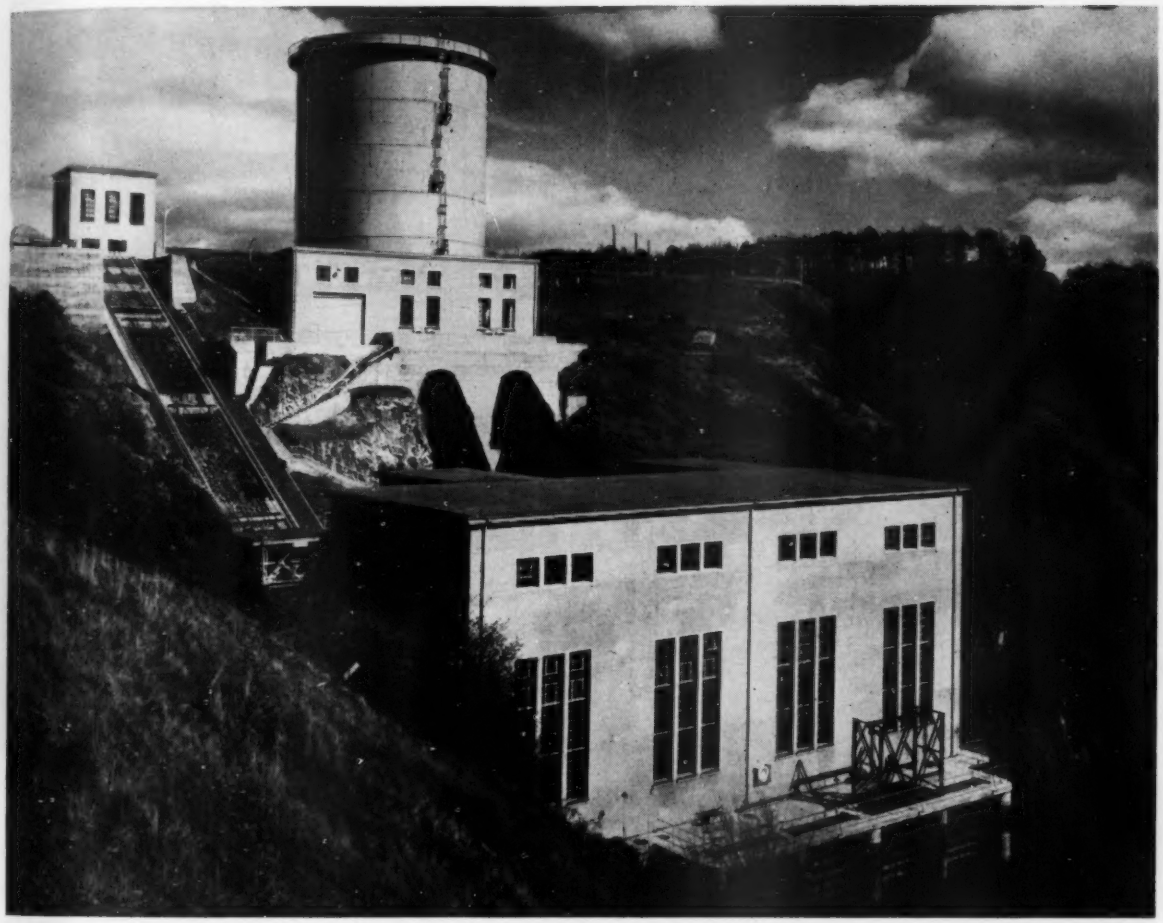
If you want to talk switchgear ···talk to Reyrolle

A. Reyrolle & Company Ltd., Hebburn, Co. Durham.

CRC 150

'ENGLISH ELECTRIC'

hydro-electric equipment



Power from the Liffey

The Pollaphuca Power Station deriving its power from the River Liffey in Eire is one of the many hydro-electric power stations equipped by 'ENGLISH ELECTRIC'.

The two 25,300 h.p. vertical shaft Kaplan type water-turbine generating sets running at 300 r.p.m. under a head of 154 ft. provide the industries and homes of Eire with many millions of units of electricity every year.

Illustrated is the exterior of Pollaphuca Power Station showing the surge tower, valve-house, pen-stocks and inclined elevator.

The ENGLISH ELECTRIC Company Limited

QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Hydro-electric Department, Stafford

Works: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL

HEJ

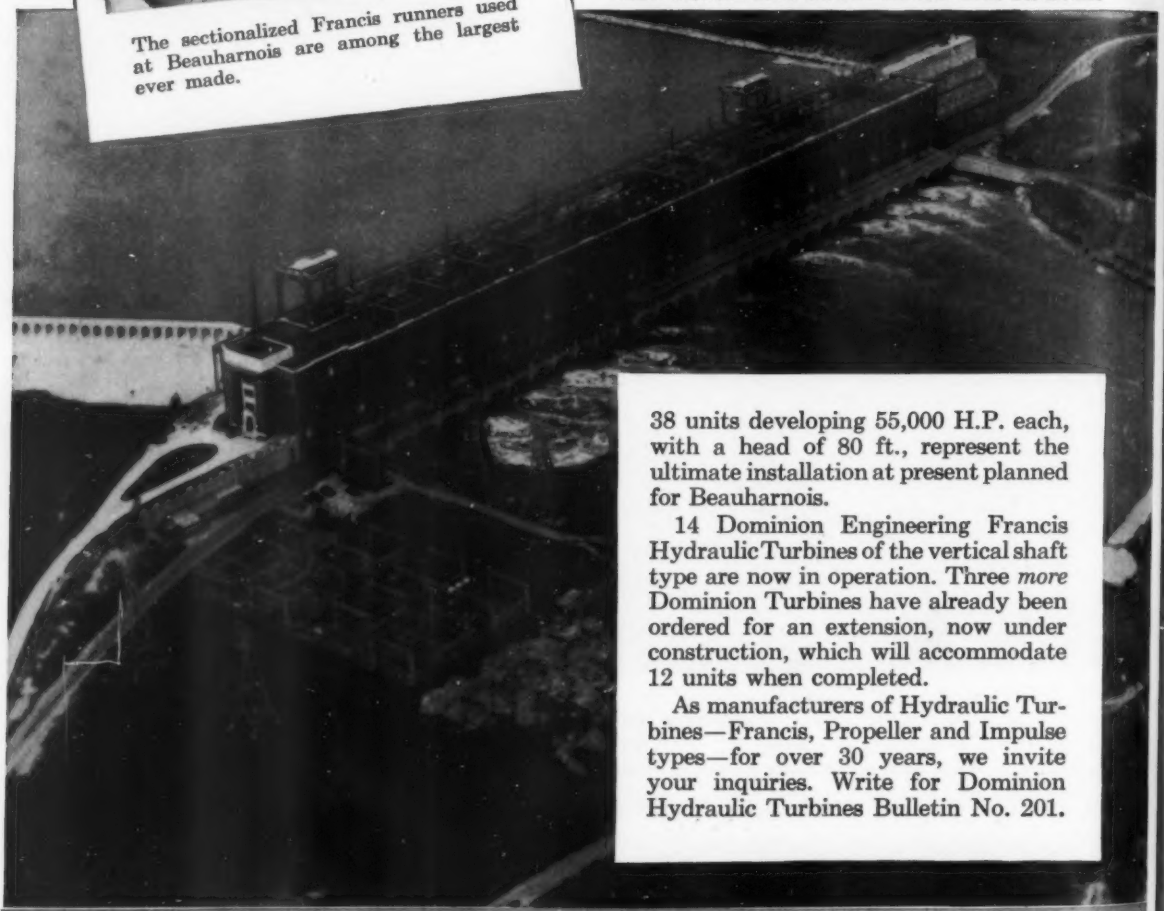
Ultimate Development of over 2,000,000 H.P. in one Canadian Plant

Dominion Engineering

Hydraulic Turbines

The sectionalized Francis runners used at Beauharnois are among the largest ever made.

The Quebec Hydro Electric Commission controlled power installation at Beauharnois near Montreal, at the down stream end of the 15 mile long, three quarter mile wide canal between Lake St. Francis and Lake St. Louis.



38 units developing 55,000 H.P. each, with a head of 80 ft., represent the ultimate installation at present planned for Beauharnois.

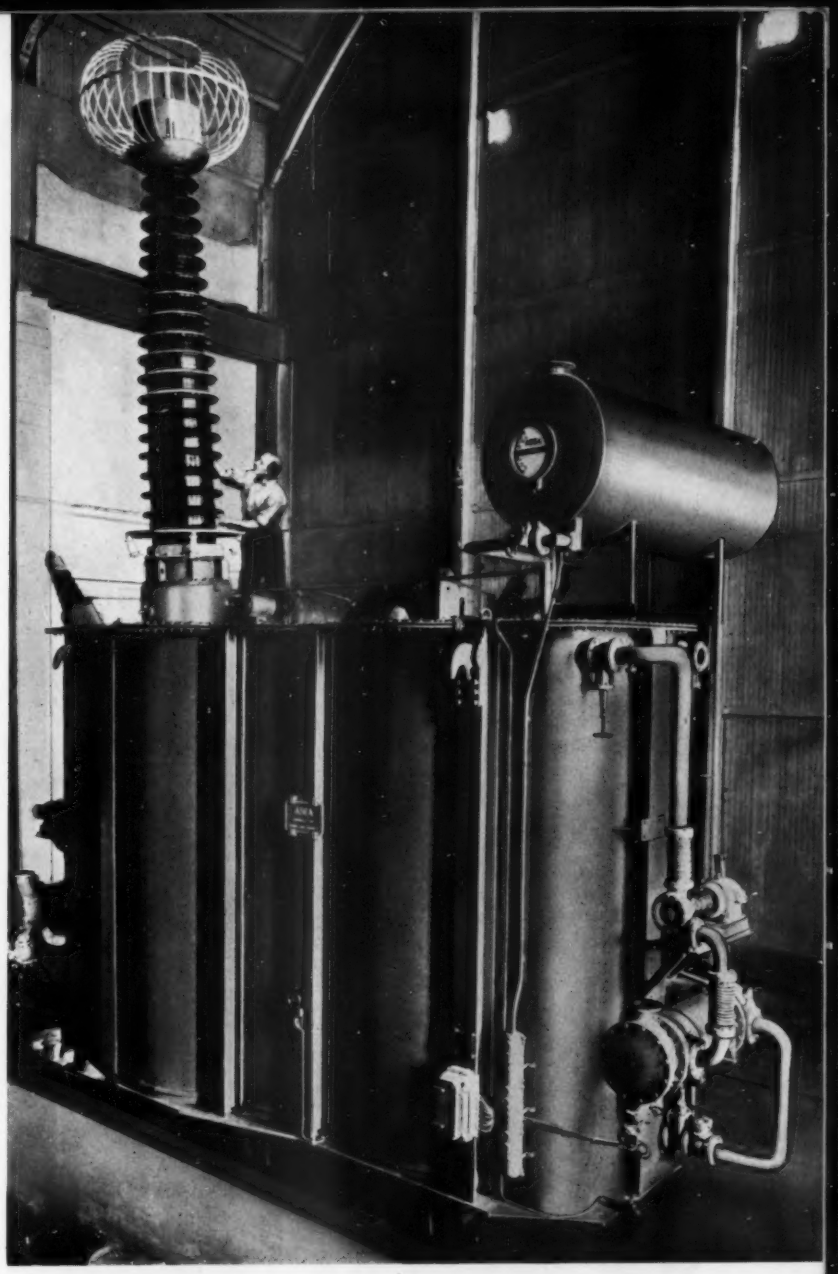
14 Dominion Engineering Francis Hydraulic Turbines of the vertical shaft type are now in operation. Three *more* Dominion Turbines have already been ordered for an extension, now under construction, which will accommodate 12 units when completed.

As manufacturers of Hydraulic Turbines—Francis, Propeller and Impulse types—for over 30 years, we invite your inquiries. Write for Dominion Hydraulic Turbines Bulletin No. 201.

DOMINION ENGINEERING
COMPANY LIMITED

MONTREAL, CANADA

CABLE: DOMWORKS



The Swedish

380kV

power transmission system

— a series of world records in electrical power engineering

The first 220 kV power transmission system in Europe was commissioned in Sweden in 1936 and employed transformers and equipment manufactured by Asea. This transmission system from the north to the central and southern parts of Sweden which carries about 1,500,000 kW has now been expanded to 6 parallel lines having a combined length of about 3,000 km (1,800 miles).

In 1946 it was decided to utilize the power of the largest waterfall in Sweden, Harsprånget, situated north of the Arctic Circle. It was necessary to transmit the power for nearly 1,000 km and after careful investigation it was decided to employ a maximum service voltage of 400 kV. This plant too is being provided with Asea equipment including generators, transformers, high voltage circuit breakers and isolators as well as other equipment.

The extensions in progress at the moment comprise 3 vertical generators each rated at 105,000 kVA, or, in other words, machines of the same order of size as those installed at the American Boulder Dam site.

The transformer deliveries comprise 34 single-phase units for 380,000 V, in sizes ranging from 43,500 to 115,000 kVA and intended to form three-phase banks of up to 345,000 kVA. In physical size some of these transformers will be the largest units ever made. The rating of the largest three-winding transformer bank, expressed as equivalent two-winding rating, amounts to almost 450,000 kVA. Built for a maximum voltage of 220,000 V instead of 400,000 V, using the same core and with the same total weight, their rating would have exceeded 200,000 kVA per unit — another world record added to those previously established by Asea.

Asea's deliveries of high voltage equipment include a number of air-blast breakers for 380 kV, 1,200 A and a rupturing capacity of 8,000,000 kVA as well as isolators and instrument transformers.

To-day as ever Asea stands in the front rank in the development of electrical power engineering. Consult our experts on all problems involving high-voltage power.

VÄSTERÅS — ASEA — SWEDEN

The safe link

We specialise in manufacturing Power Transformers for Generation. Transmission and Distribution. All YORKSHIRE Transformers are designed, constructed and tested to the corresponding British Standard Specification.

We make Transformers to suit all requirements up to 45,000 k.V.A. - 132,000 volts.

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YORKSHIRE ELECTRIC TRANSFORMER Co LTD DEWSBURY · ENGLAND

* * *

TANGANYIKA
The Pangani Scheme

The lower photograph shows two of the machines built by us. Three 3600 BHP and one 7200 BHP turbines are in service and a further 7200 BHP unit will shortly be installed. All are horizontal shaft Francis turbines, the larger sets being of the twin runner type. The whole of the design and construction of Pangani Scheme was executed by Messrs. Balfour, Beatty & Co. Ltd.

An impression of the Pangani Falls.

Boving

WATER POWER ENGINEERS

Head Office:

56, KINGSWAY, LONDON, W.C.2,

Branch Offices: Wellington, Druids Chambers, Woodward Street.
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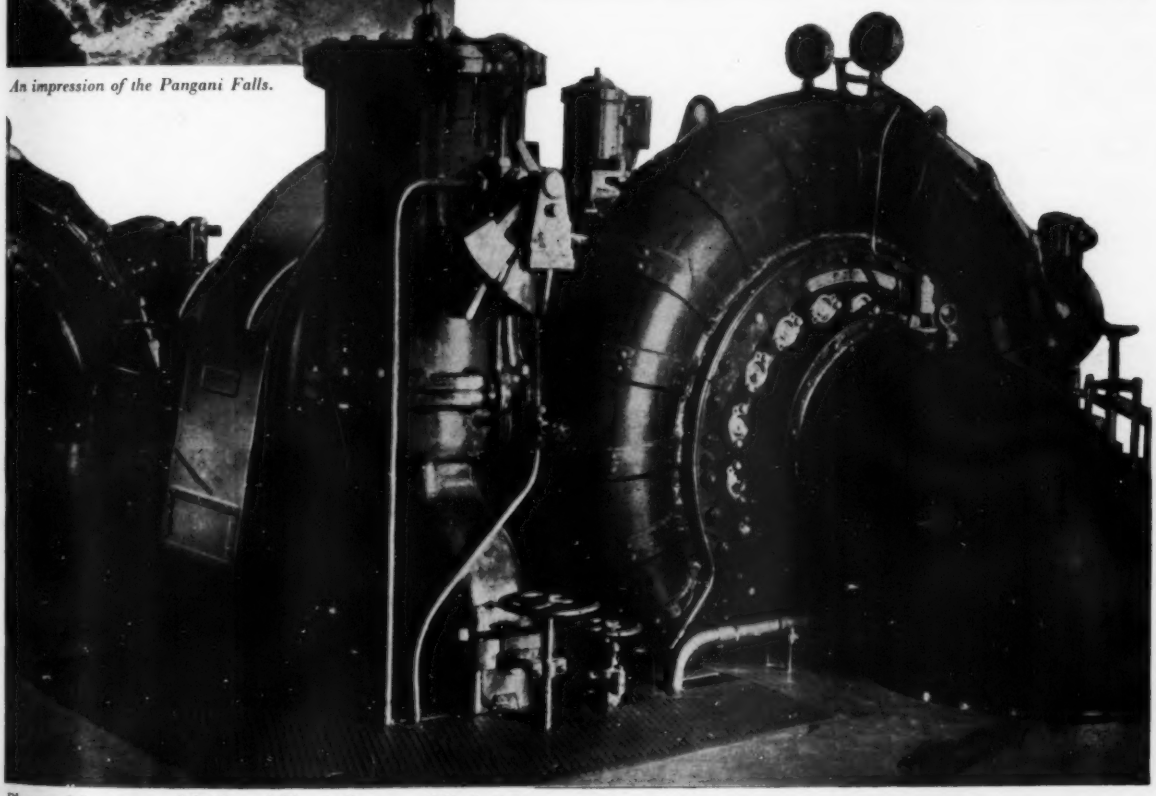
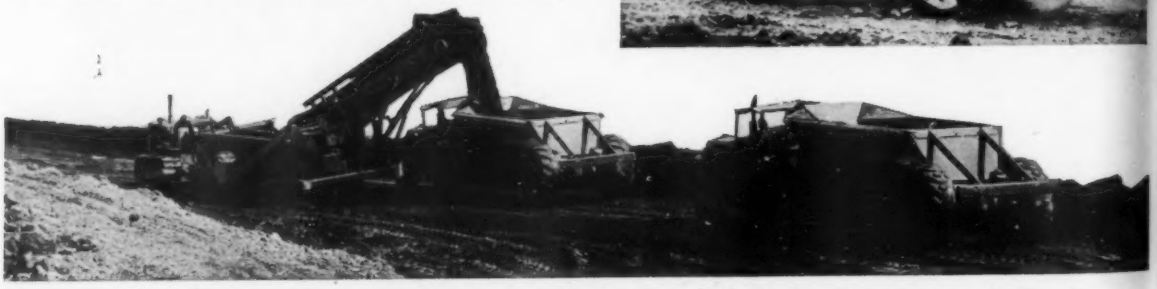


Photograph by courtesy of the General Electric Company of England.

Euclid *means...*

...OFF-THE-HIGHWAY HAULING EQUIPMENT

Built by the pioneer manufacturer of earthmoving equipment, Euclids—powered by the world-famous CUMMINS Diesel Engine—incorporate the know-how of years of experience. Every Euclid model is engineered specifically for off-the-highway work; all of the production and service facilities of Euclid are devoted to this type of equipment. Heavy-duty design and construction throughout ensure long life and dependable performance . . . more loads per hour and more profit per load on the toughest jobs.
Euclid Rear-Dump Wagons are available for Sterling. Place your order now. All orders executed in strict rotation.



A complete After-Sales Service for all Euclid Equipment is available through the sole distributors

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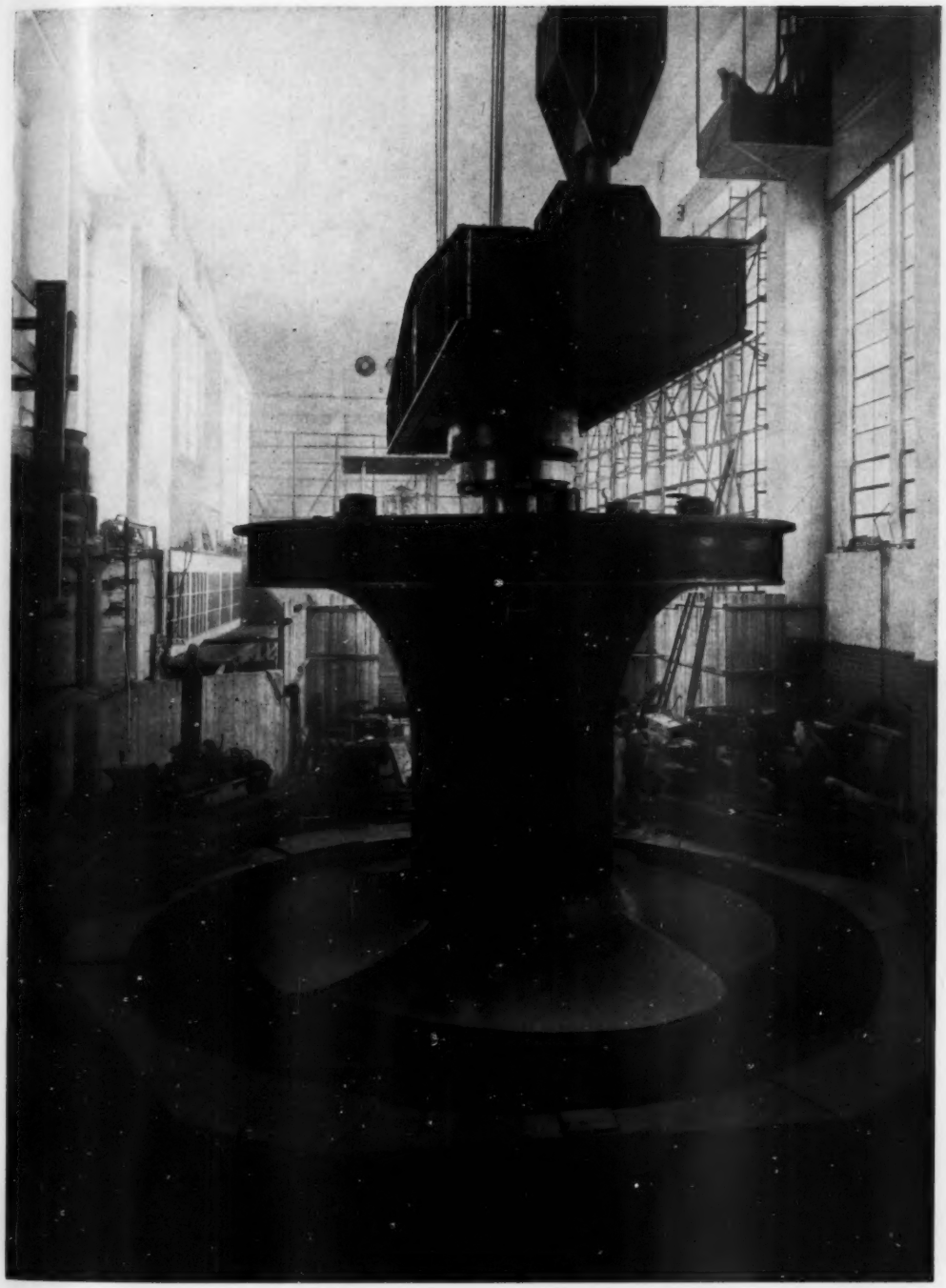

ESCHER WYSS ZURICH

1805 saw the foundation of the firm of ESCHER WYSS and 1840 the construction of the first water turbines. To-day, over one hundred years later, we have built Kaplan, Impulse and Francis turbines developing the largest outputs and operating under the highest heads. Furthermore, storage pumps up to 62,000 h.p. input. Our experience in manufacture and in installation work all over the world is at your disposal.

ESCHER WYSS LTD., ZURICH (SWITZERLAND)

TUNNEL AT BOWLAND FOR MANCHESTER CORPORATION WATERWORKS
Engineer and Manager—Alan Atkinson, Esq., M.Eng., M.I.C.E., M.Inst.W.E.

The CEMENTATION COMPANY LIMITED

This tunnel, ten miles long, forms the middle section of the aqueduct which when completed will bring water from Haweswater in the Lake District to Manchester. The conditions for tunnelling under the Bowland Hills are difficult, varying from soft mudstones to sandstones containing water at high pressure, such as in the heading shown above from which over two million gallons of water are being pumped each day. Despite these varying and difficult conditions, a progress of 334 feet has been obtained in one week in ground requiring continuous steel arch support right up to the face.

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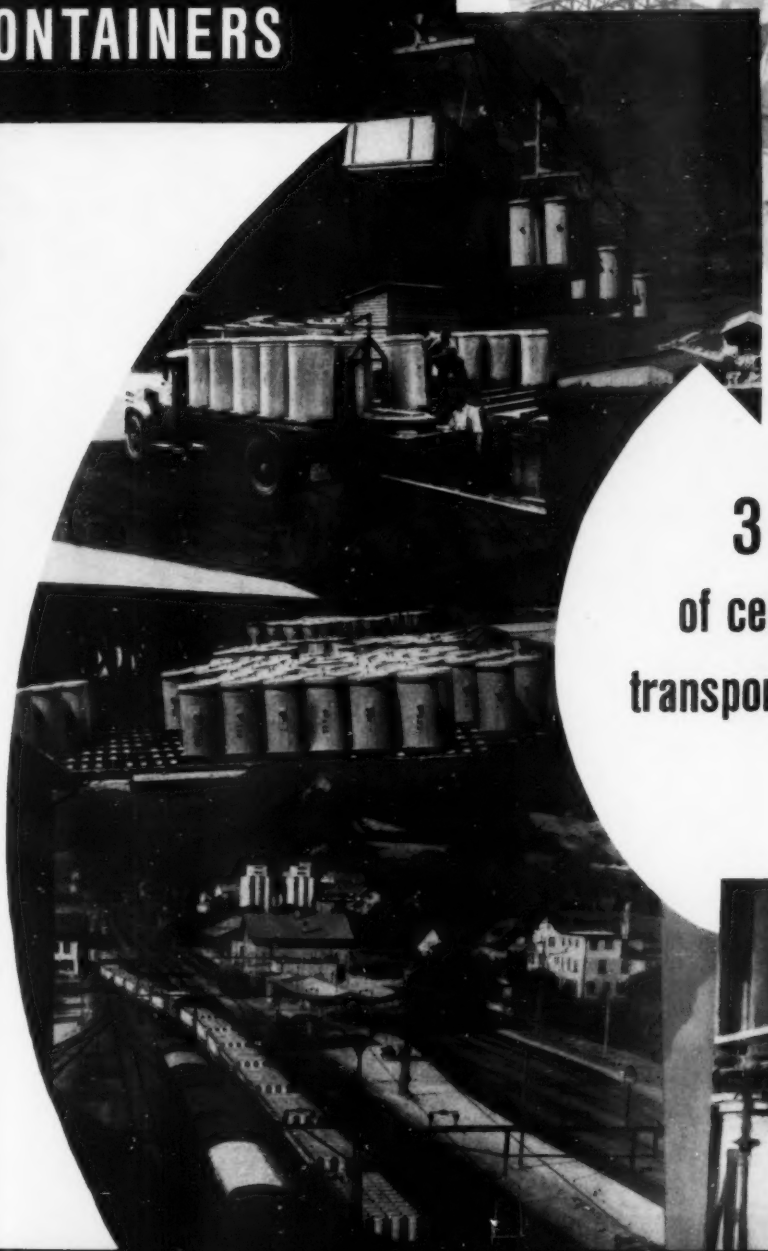
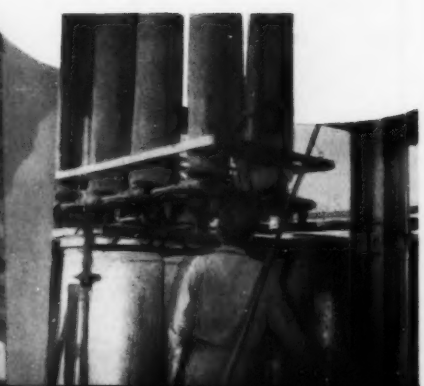
Transport Cement to inaccessible sites in TM BULK CONTAINERS



3 million tons

of cement have been transported by TM



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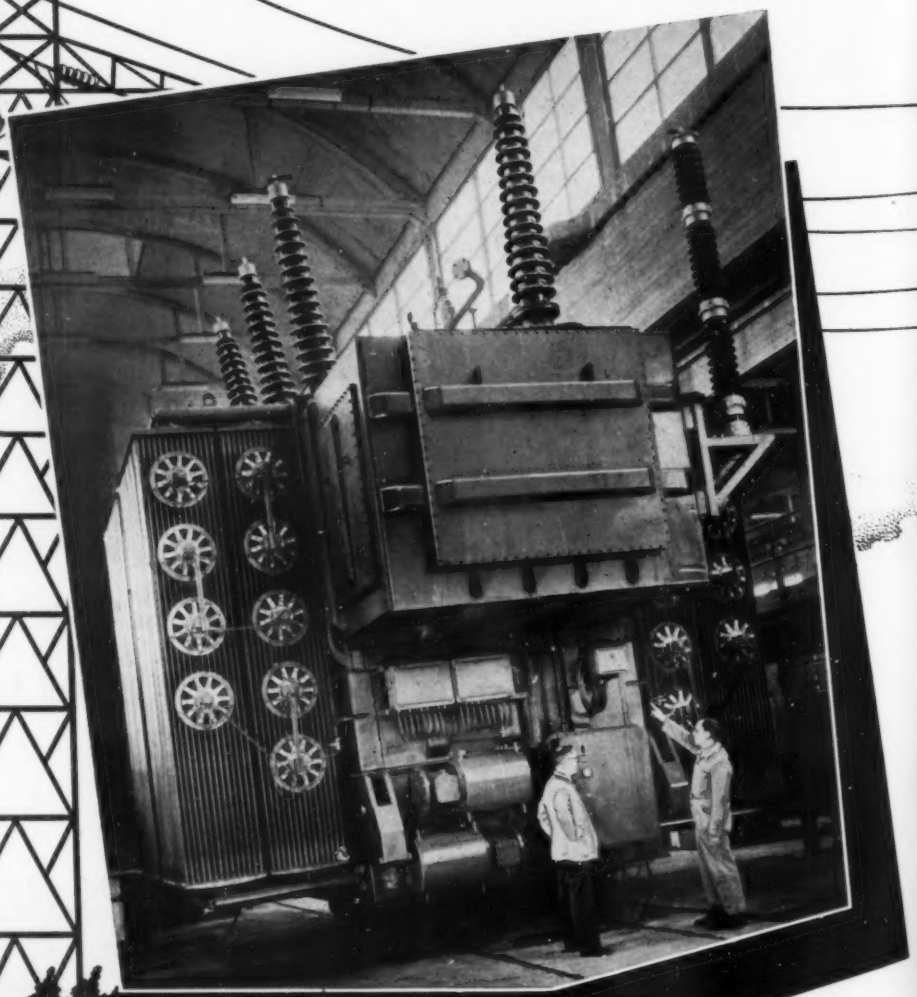
TM-TRANSPORTS MÉCANISÉS S. A. BAHNHOFSTRASSE 24 **ZURICH 1** (SWITZERLAND)

One of the 4 TRANSFORMERS

"Shell-Type"

OF 75 000 kVA, INTENDED FOR THE BELGIAN CENTERS OF INTERCONNECTION FOR NETWORKS OF 150/70 kV.



75 000 kVA

3 WINDINGS : 150/70/10 kV:
ON LOAD VOLTAGE REGULATION : ± 17,5 % ON THE 150 kV SIDE
3 RANGES OF LOAD : 45 000 kVA - 60 000 kVA - 75 000 kVA according to the type of cooling system.

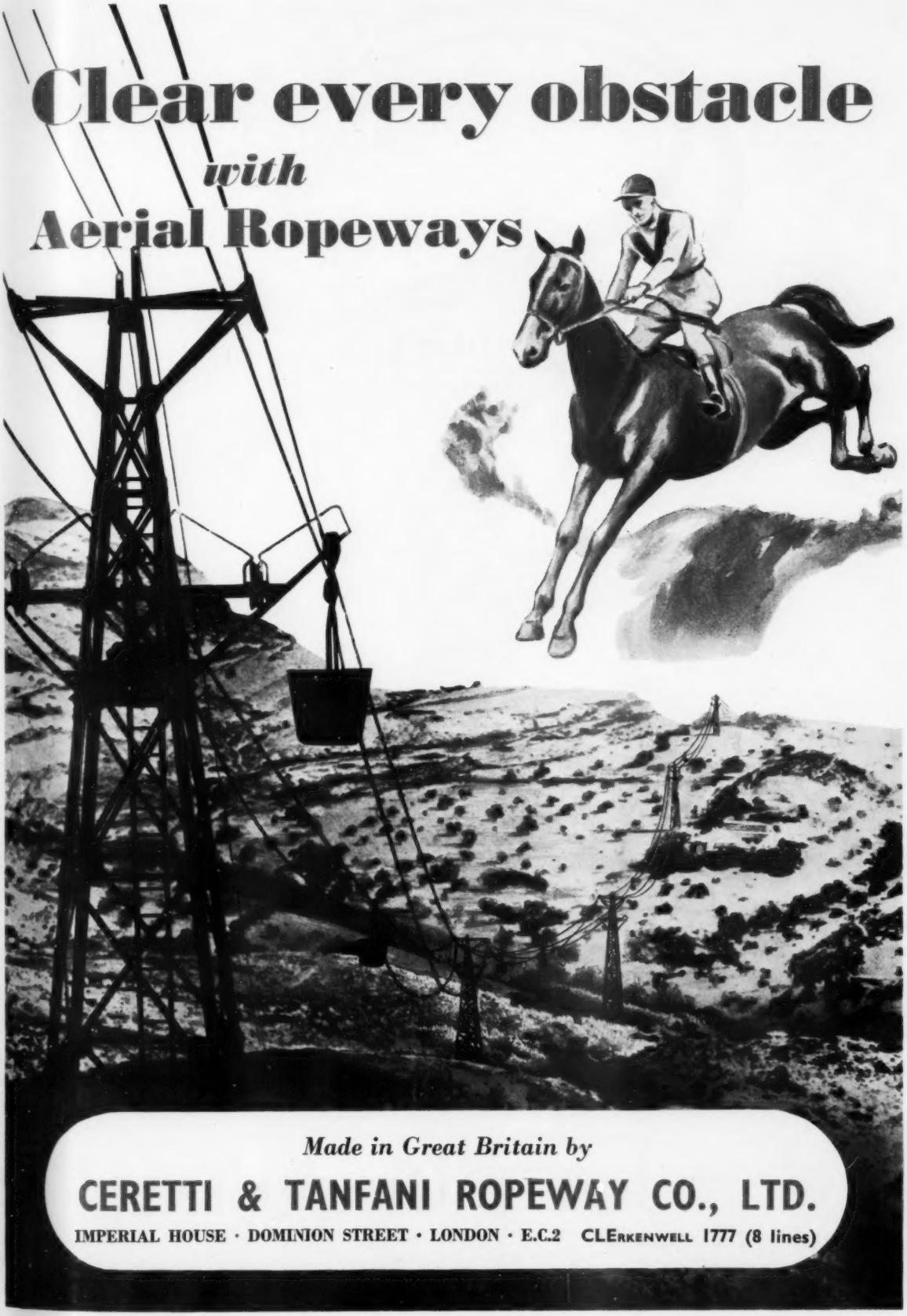
Ateliers de Constructions Electriques de Charleroi

CHARLEROI CAC/EV

Clear every obstacle

with

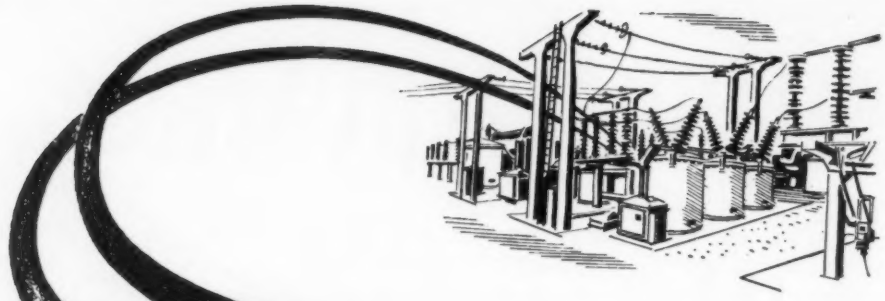
Aerial Ropeways



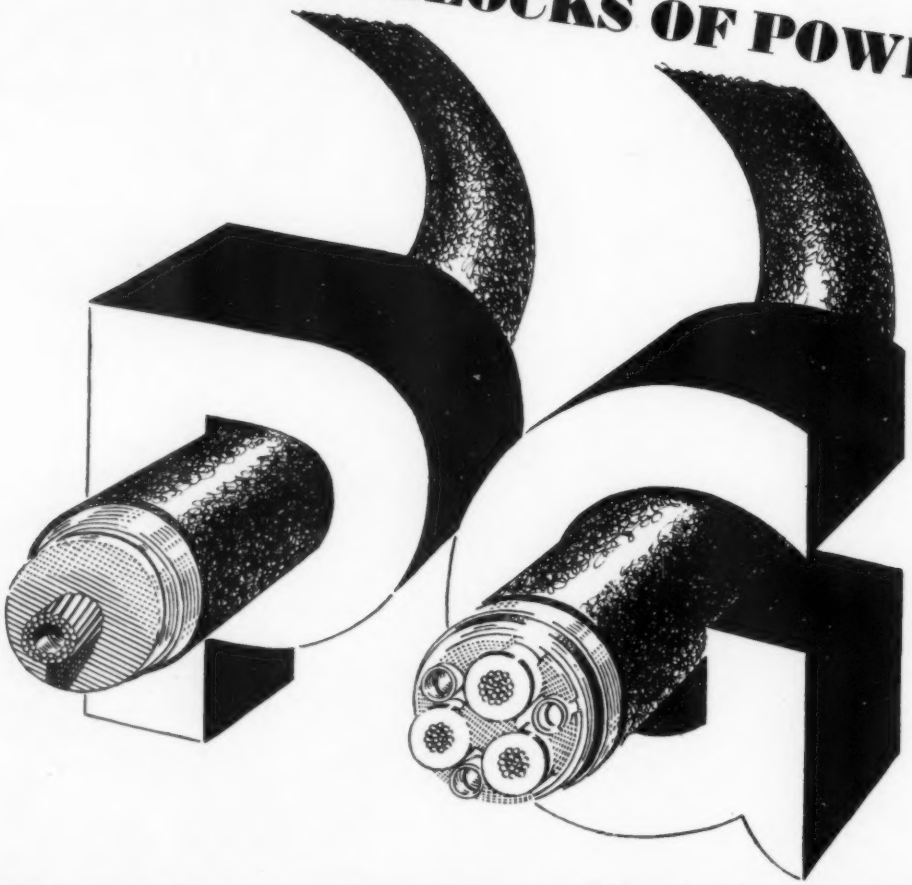
Made in Great Britain by

CERETTI & TANFANI ROPEWAY CO., LTD.

IMPERIAL HOUSE · DOMINION STREET · LONDON · E.C.2 CLERKENWELL 1777 (8 lines)



FOR LARGE BLOCKS OF POWER



OIL-FILLED SUPER TENSION CABLES

33 kV to 330 kV

PIRELLI-GENERAL

MANUFACTURERS OF EVERY KIND OF ELECTRIC CABLE

PIRELLI-GENERAL CABLE WORKS LIMITED, SOUTHAMPTON
(Associated Company of the General Electric Company Limited)

Work on the diversion tunnel and channel at the Weir Wood Reservoir Contract, which is one of the water conservation schemes being carried out by the Company.

Consulting Engineers: Herbert Lapworth Partners

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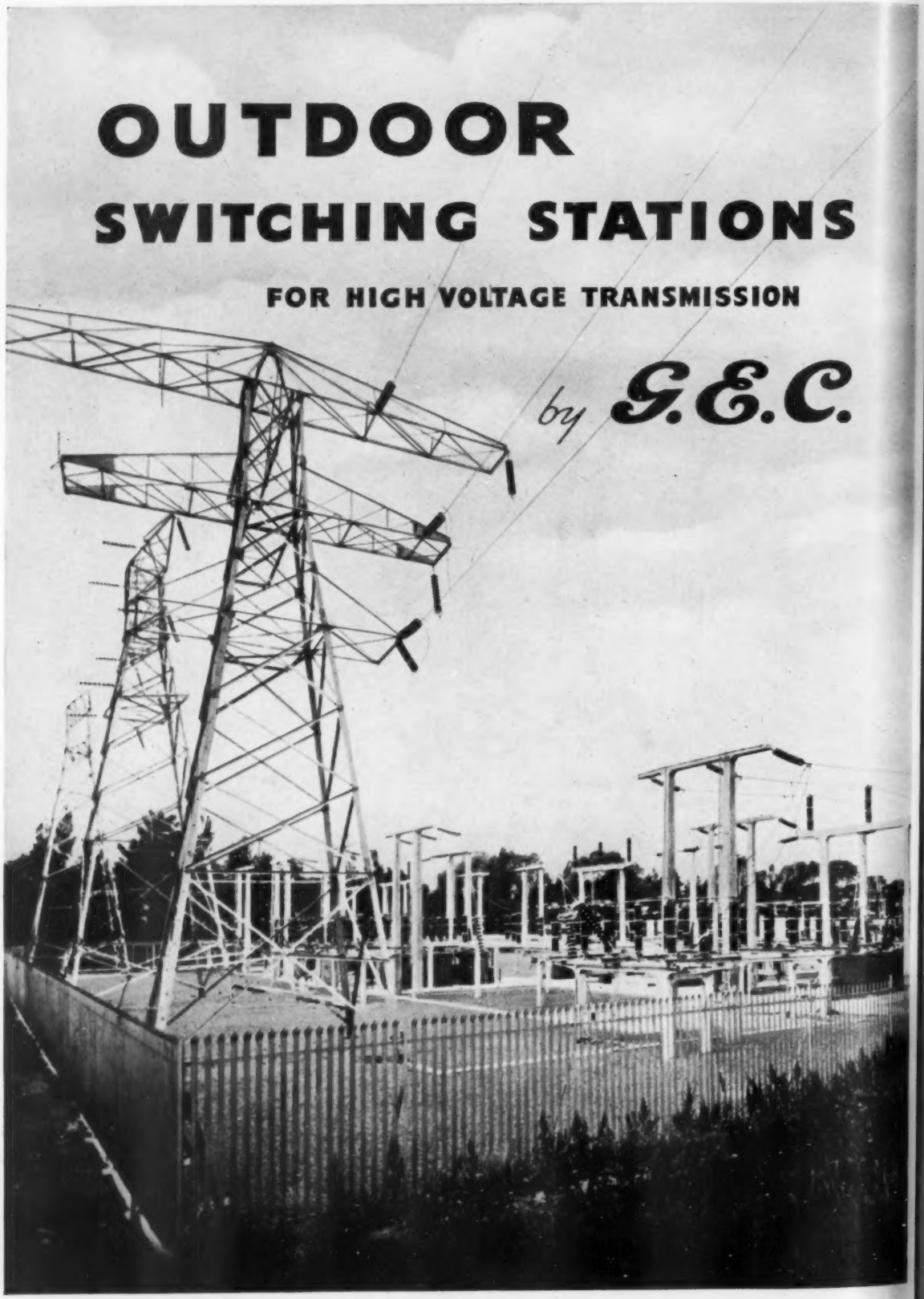
Building & Civil Engineering Contractors

OUTDOOR
SWITCHING STATIONS
FOR HIGH VOLTAGE TRANSMISSION

by G.E.C.



THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

AERIAL CABLEWAYS

Henderson Aerial Cableways have solved the problem of raising, transporting and depositing concrete, shuttering and other materials for the construction of large Dams and Barrages.

Henderson Cableways are being used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

DERRICK CRANES

Henderson Cranes are chosen so often because of their speed and versatility in lifting materials. Their safety and economy in operation are also assured. Supplied to many leading contractors Henderson Derrick Cranes of all types and capacities can be manufactured for steam, electric, petrol or diesel drive. Cranes can also be fixed or travelling types. Normal sizes are from 10 cwt. to 60 tons Load capacity. With jibs up to 120 feet.

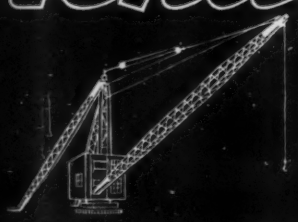
View of Henderson Cableways during the construction of the Claerwen Dam, courtesy of the Birmingham Corporation Water Works. Contractors Messrs. Edmund Nuttall Sons & Co., Ltd.

Henderson

Aerial Cableways

AND DERRICK CRANES

FOR HYDRO ELECTRIC SCHEMES



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Quarry to Batching PLANT

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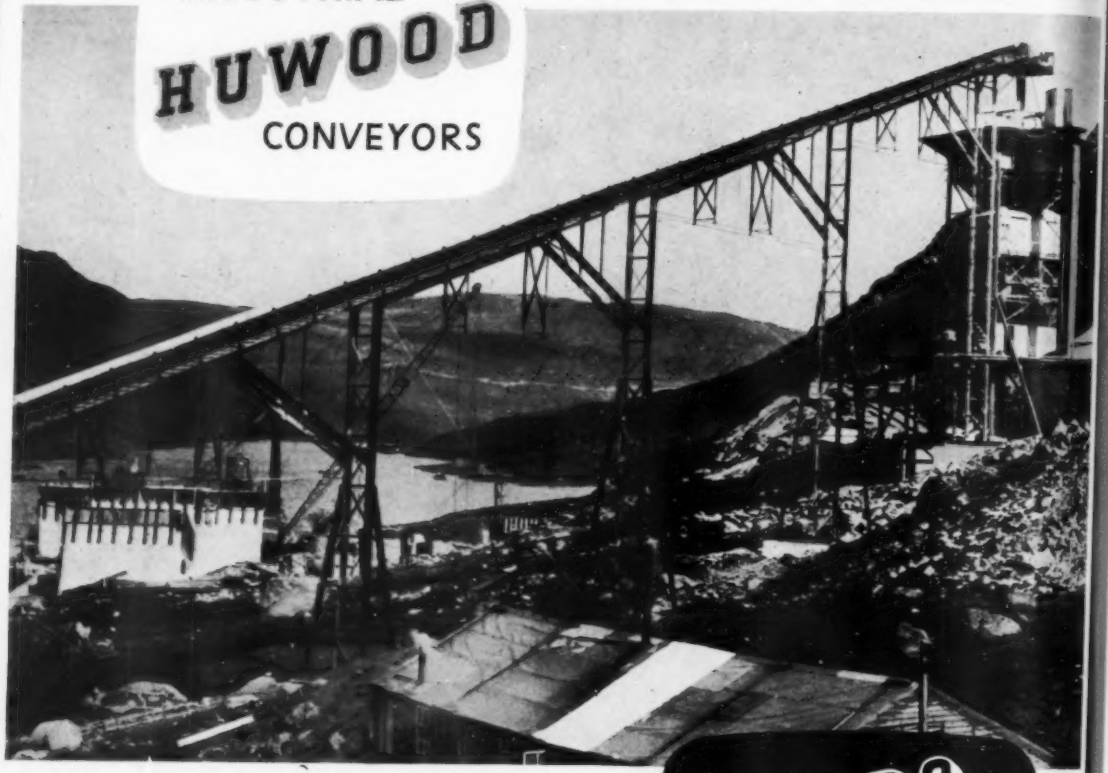

HYDRO ELECTRIC

SCOTLAND · TUMMEL GARRY · LOCH SLOY
ERROCHTY DAM

AFRICA · OWEN FALLS · UGANDA

INDIA · HIRAKUD DAM PROJECT

HUGH WOOD & CO. LTD.

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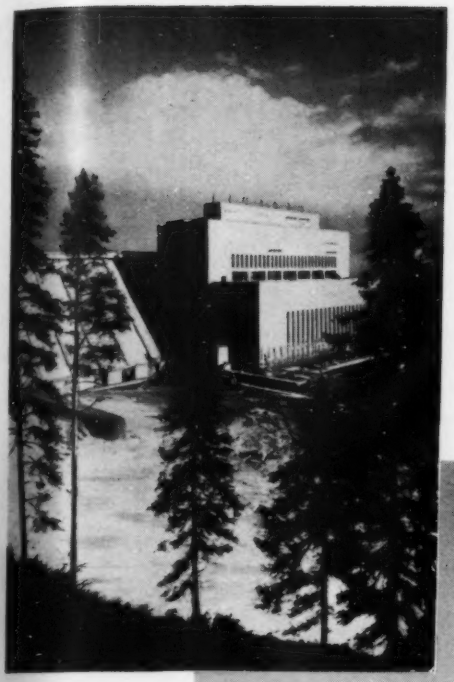
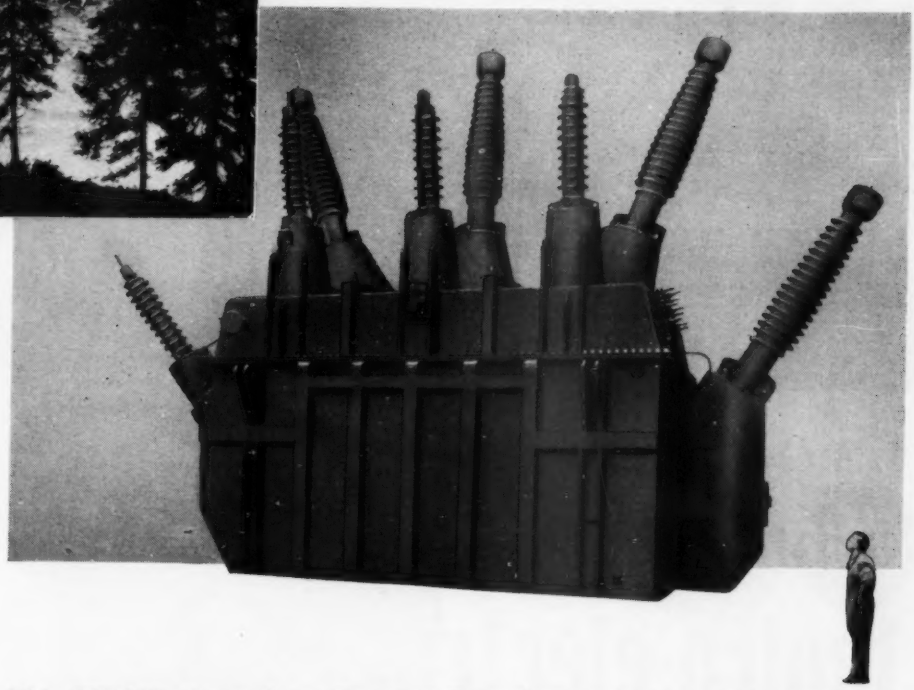
A 3-Phase 230 kV FERRANTI TRANSFORMER for Water Power



The Pyhäkoski Power Station, total output 108 MW, the largest in the current water-power programme of Finland.



This 230 kV three-phase Ferranti Transformer is one of five being installed at the Pyhäkoski Generating Station and Hikia Transforming Station of the Imatra Power Company, Finland.
They are the first 230 kV transformers to be ordered in Britain, and were adopted because of their advantages in cost and efficiency. Total weight of each transformer and cooling gear is 220 tons.

FERRANTI

FERRANTI LTD

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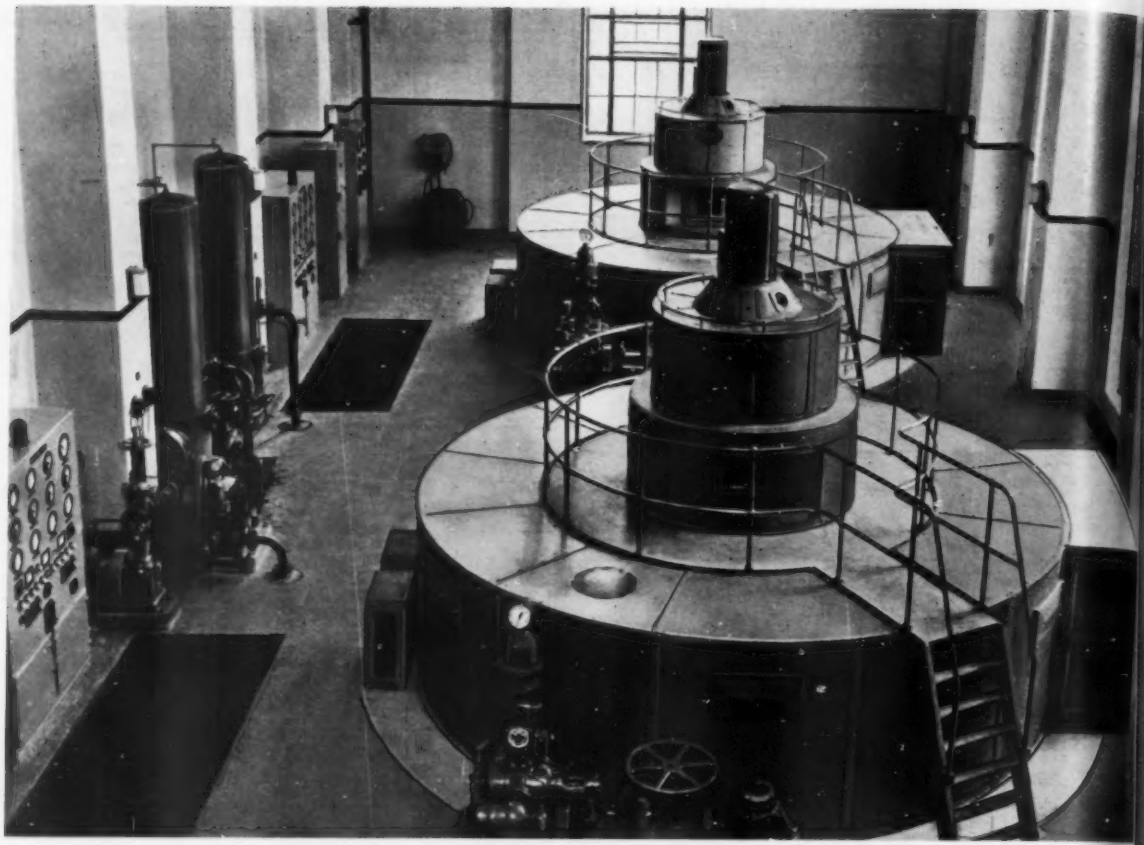
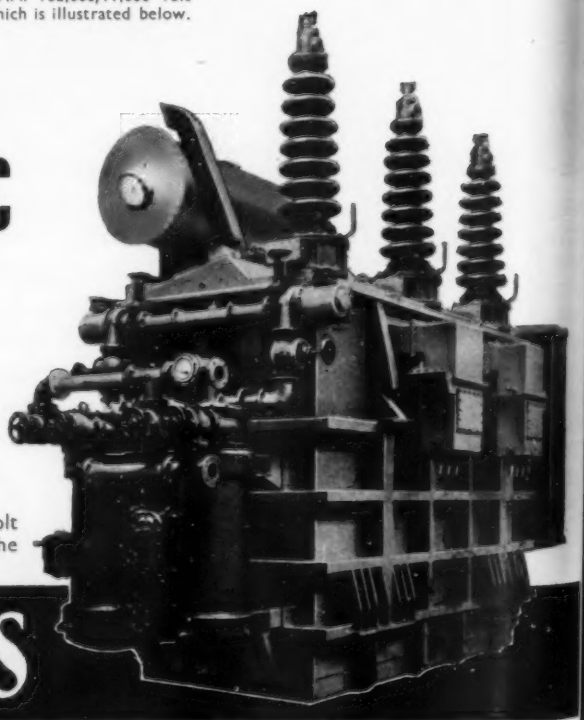


LOCH FANNICH PROJECT, North of Scotland Hydro-Electric Board. View of Grudie Bridge power station showing two 12,000 K.W. 11,000 volt, 500 r.p.m. vertical generators. The installation includes two 20,000 K.V.A. 132,000/11,000 volt water-cooled transformers, one of which is illustrated below.

PEEBLES

hydro-electric plant

Bruce Peebles build large and small generators for all types of water turbines, and transformers up to the largest sizes for hydro-electric power distribution.

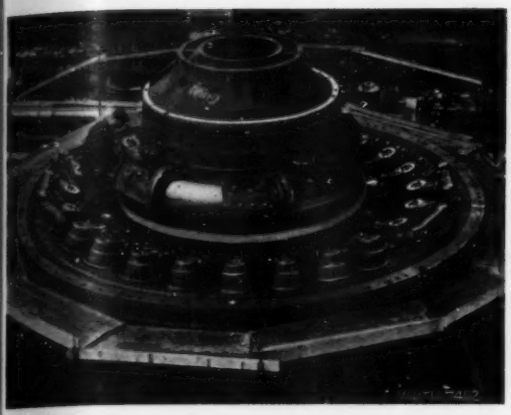


20,000 kVA. 132,000/11,000 volt water-cooled transformer for the Loch Fannich scheme.

BRUCE PEEBLES

Advertisement of BRUCE PEEBLES & CO. LTD. · ENGINEERS · EDINBURGH · SCOTLAND

Innovations in the design of



Voith-Kaplan Turbines

Turbine cover welded steel throughout

"Annular" servomotors for gate regulation

Oil supply for runner blade adjustment through top main shaft guide bearing below alternator.

"Annular" servomotors and thrust bearing on turbine cover

We have already adopted at an earlier date:

The undivided shaft

for turbine and generator and

Thrust bearing

on turbine cover

Some

460 Kaplan Turbines

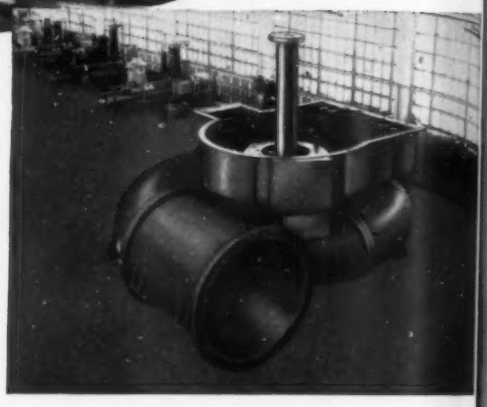
for small and large outputs have been supplied for use on the home market and abroad

Turbine shaft with thrust bearing and special swinging equipment used for the alignment of shaft

J. M. Voith G.m.b.H. Engineering Works

Heidenheim (Brenz), Germany

The *"Anderson Ranch"* POWER PROJECT
United States Bureau of Reclamation



hydraulic turbines by **LEFFEL**

Anderson Ranch Dam, located on the Boise River in Idaho, U. S. A., is the highest earth-fill dam in the world. Two Leffel turbines are installed in the Anderson Power Plant which provides power for the surrounding area. The turbines are of the cast steel spiral case, vertical Francis type and each is maximum rated at 28,250 HP, under 324 ft. net head, speed 277 RPM.

When you consider turbines for your power project (whether it is a new installation or the expansion of an existing installation) we ask you to keep in mind the services which are offered by Leffel. Our 90 years of experience, our large modern plant, our thorough workmanship — all are ready to serve you.

With a structural height of 456 feet, a base width of 2,650 feet and a crest length of 1,350 feet the Anderson Ranch Dam contains nearly 10,000,000 cubic yards of earth and rock. The reservoir behind the dam will hold 493,200 acre-feet of water.

1083

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 90 YEARS

HIGH TENSION SALVI IFI MILANO LINE FITTINGS

For 30 years Messrs. A. Salvi & Company, Milano, Italy have specialised in the design and manufacture of complete equipment for Overhead Transmission Lines, covering a complete range of Line Material, including Clamps, Fittings and all Accessories.

The Works of the Salvi Company are engaged exclusively in the production of high grade Fittings for High Tension and Extra High Tension Transmission Systems, up to and including pressures of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

We shall be glad to receive enquiries and to provide a data sheet indicating the details we require to enable us to quote for your requirements.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES AND BRITISH COLONIES AND PROTECTORATES

FERRUM (ENGLAND) LIMITED • ENGINEERS • STAFFORD HOUSE • 43 NORFOLK STREET • LONDON, W.C.2

The fastest, most economical method of placing BULK CONCRETE giving

Blaw Knox concrete pipe lines on the construction of the Royal Festival Hall—Main Contractors—Messrs. Holland & Hannen and Cubitts Ltd.

BETTER
placing of high quality concrete at the lowest cost per cubic yard.

BETTER
placing on awkward sites—uphill, downhill and underwater . . . traversing highways and railway tunnels without obstructing traffic.

BETTER
placing without rehandling problems . . . no chutes, hoists, towers, buckets, cranes, etc.

BETTER
utilisation of man-power—with one man more concrete can be placed than by a whole team using old fashioned methods.

PUMP IT

Basic component of the system is the **BLAW KNOX** portable, two speed, heavy duty, single acting horizontal piston pump. Capacity 15-20 cubic yards of concrete per hour.

PIPE IT

BLAW KNOX Concrete Pipelines comprise 6″ steel pipes in various lengths up to 10′ and simple, quick-acting couplings with rubber seatings for fast assembly and dismantling. During pumping the pipeline is completely filled, concrete moving through in synchronous impulses in an excellent state of uniformity.

PLACE IT

Concrete is poured straight into the forms, exactly where it is needed.

Blaw Knox engineers will be glad to advise on the application of the Concrete Pump to specific jobs.

BLAW KNOX

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BLAW KNOX *Concrete by Pipeline*

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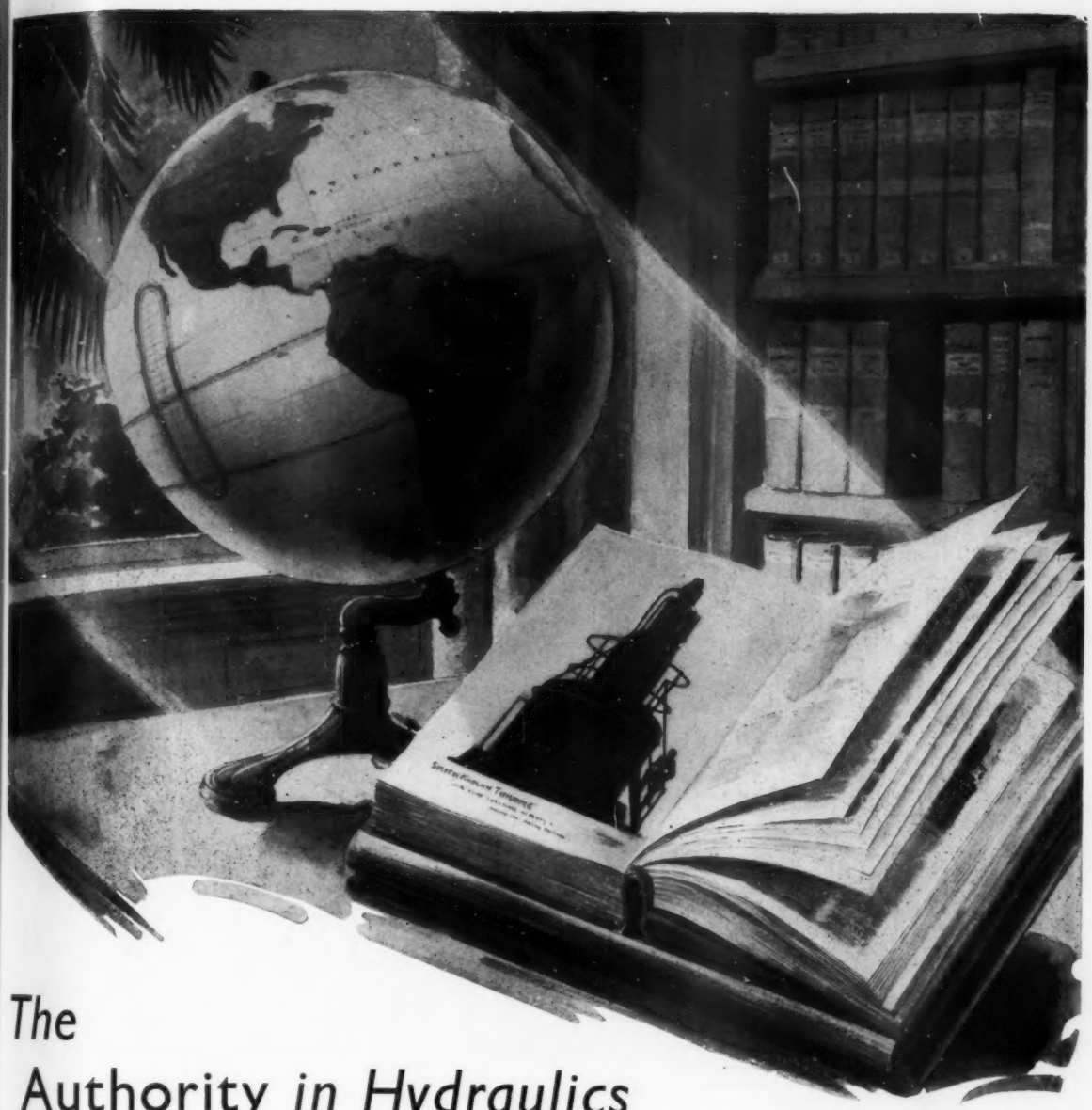

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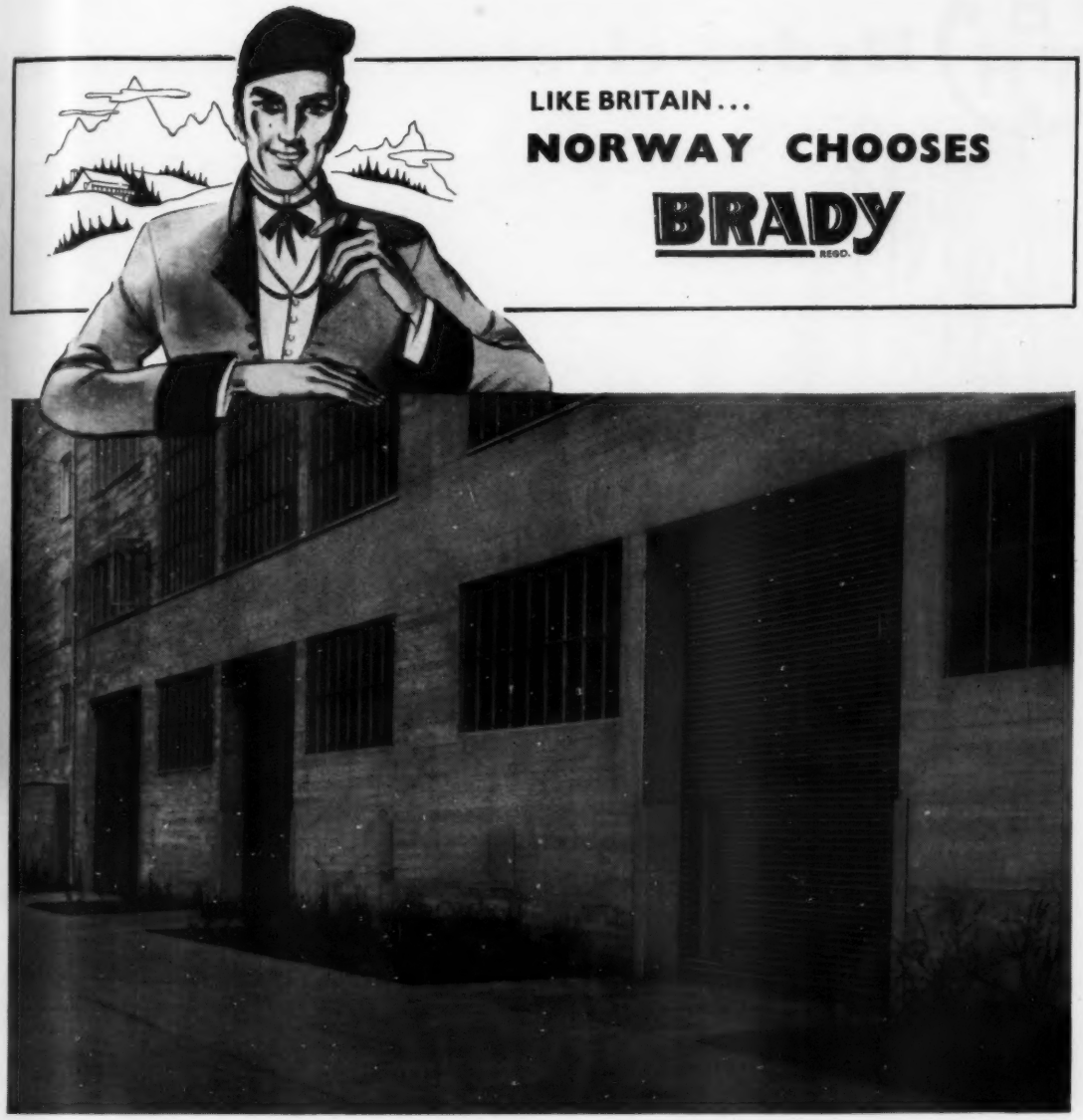

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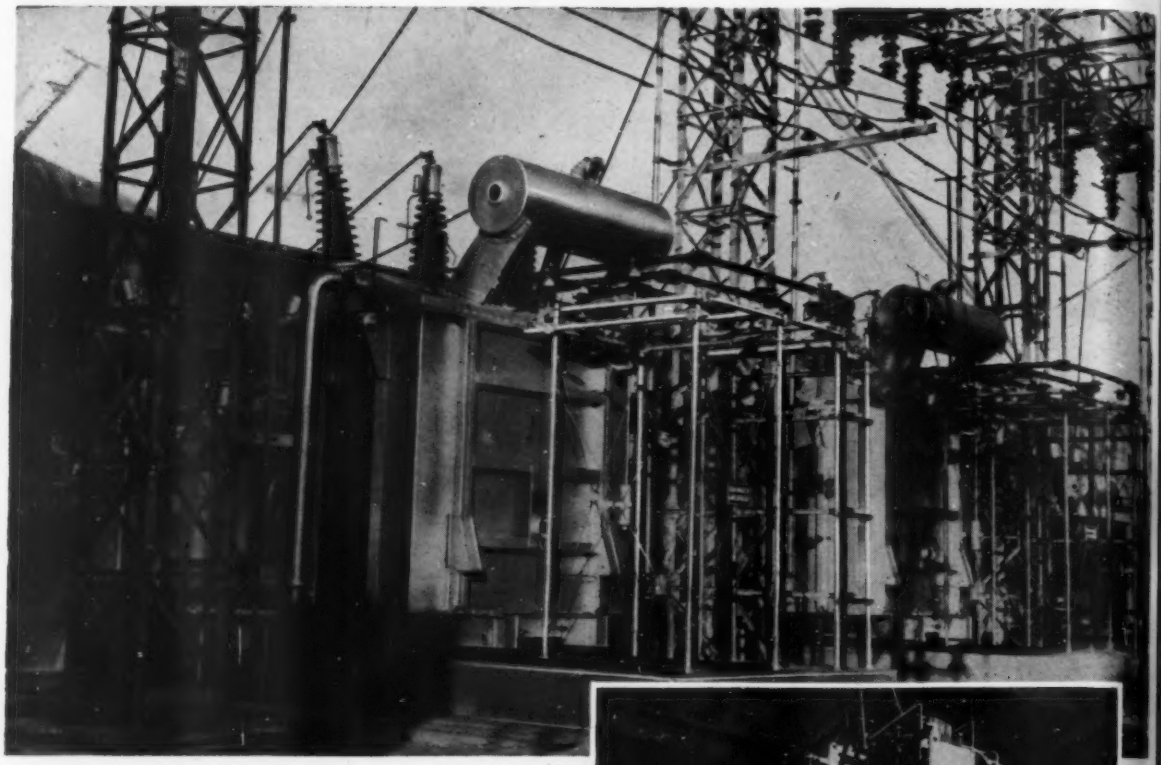

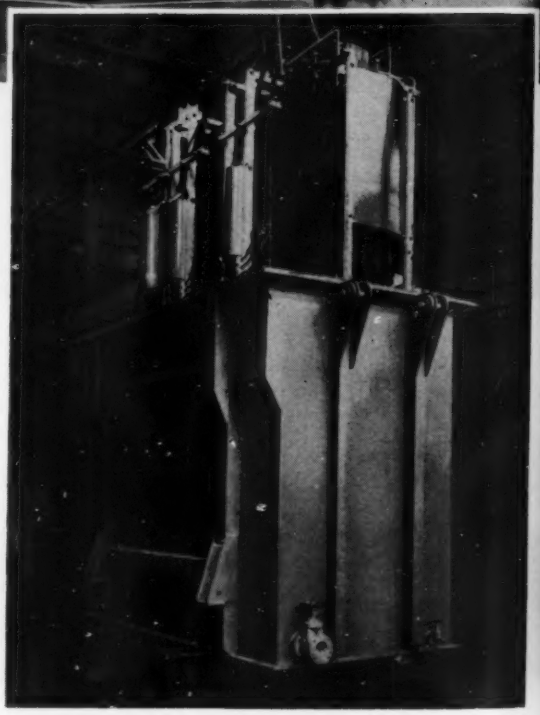

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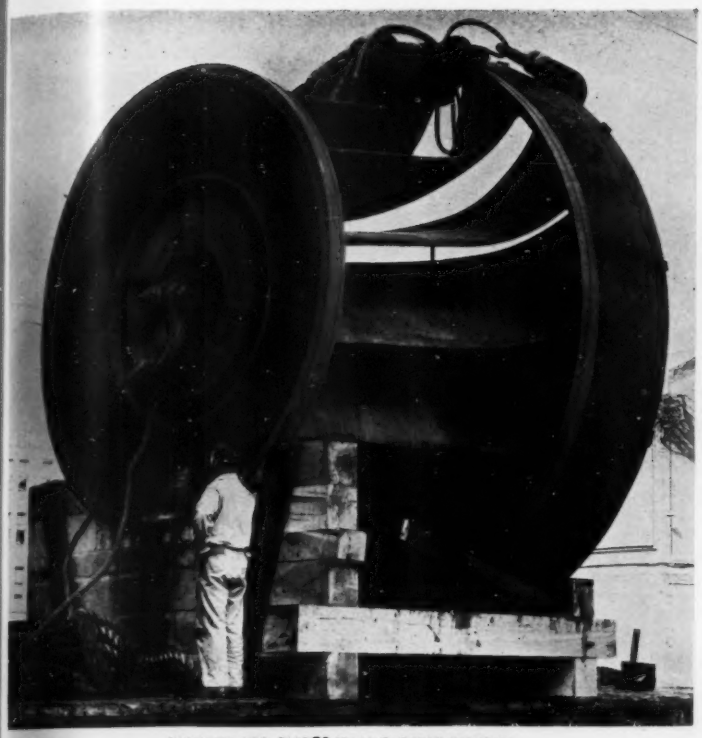

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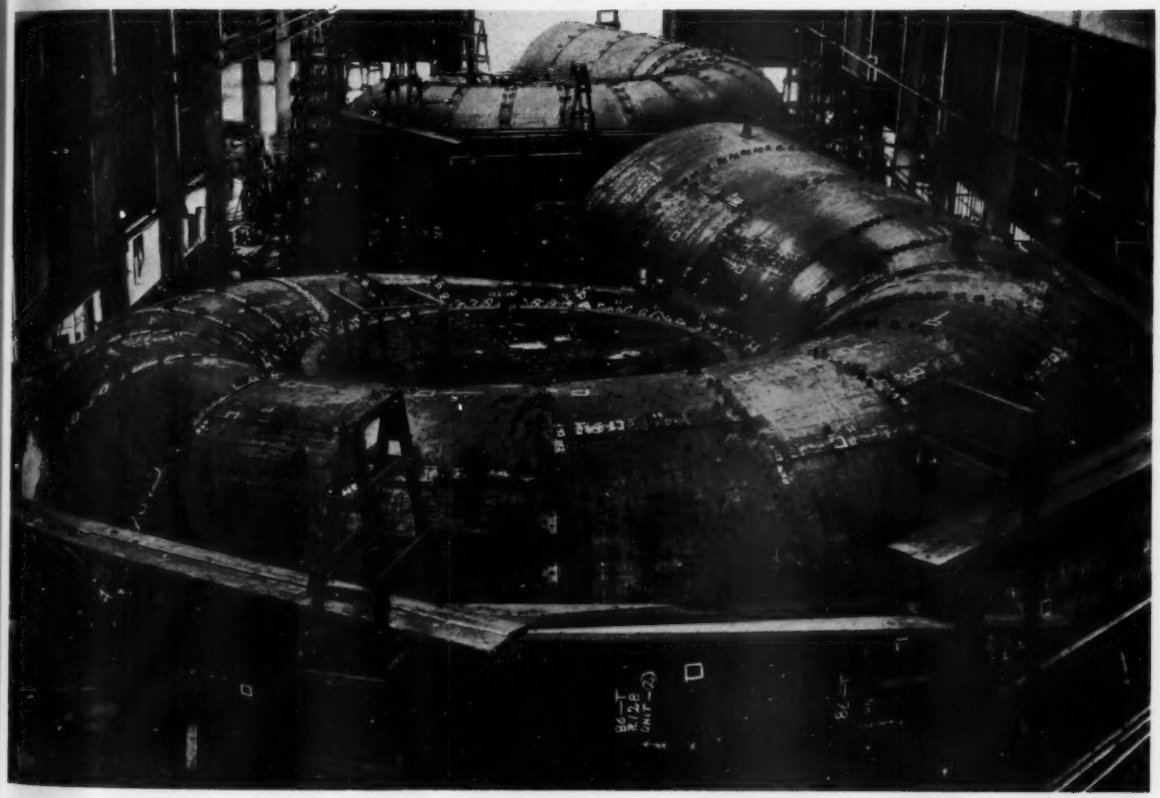

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NEWPORT NEWS
SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

Moyopampa power station (Peru)
View of surge chamber with town of Chosica in background. Two Brown Boveri 30,000 kVA hydro-electric alternators have been supplied for this power station.

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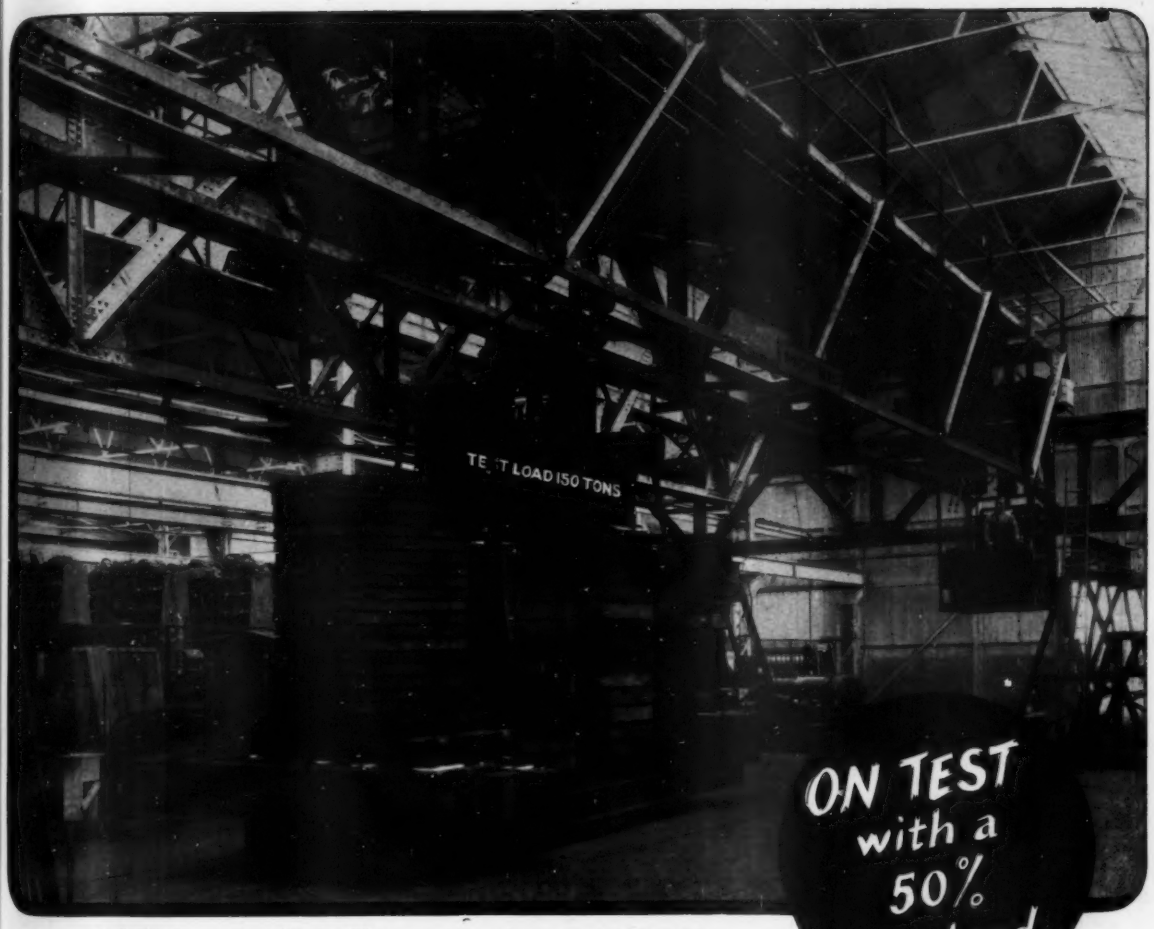

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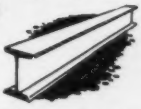
How do you pronounce

. . . with a soft "G" as in Gin ?

. . . or with a hard "G" as in  Girder ?

We say "JILKS", but with typical English perversity make it more difficult by putting "Gilbert" in front and "Gordon" behind.

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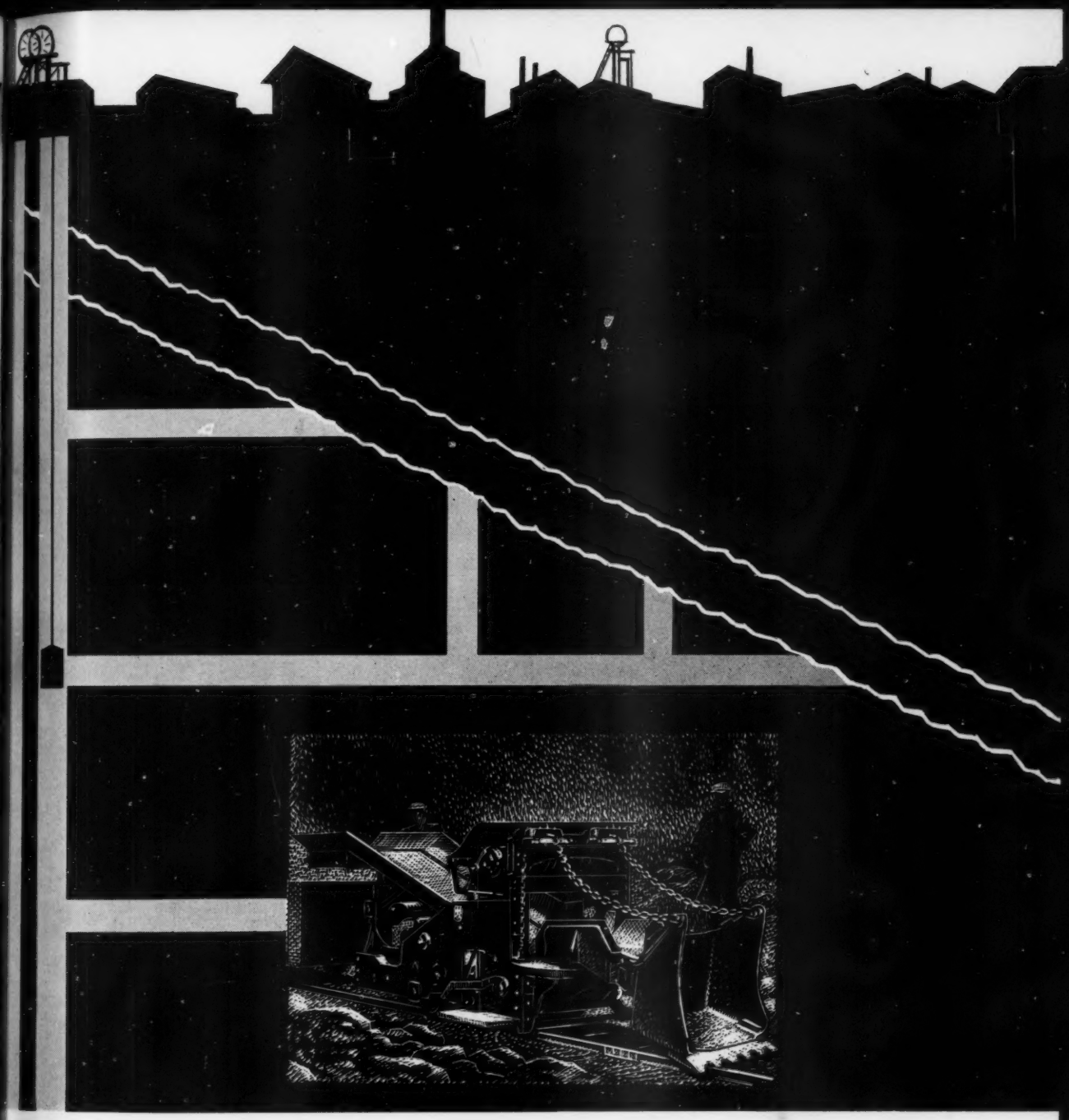

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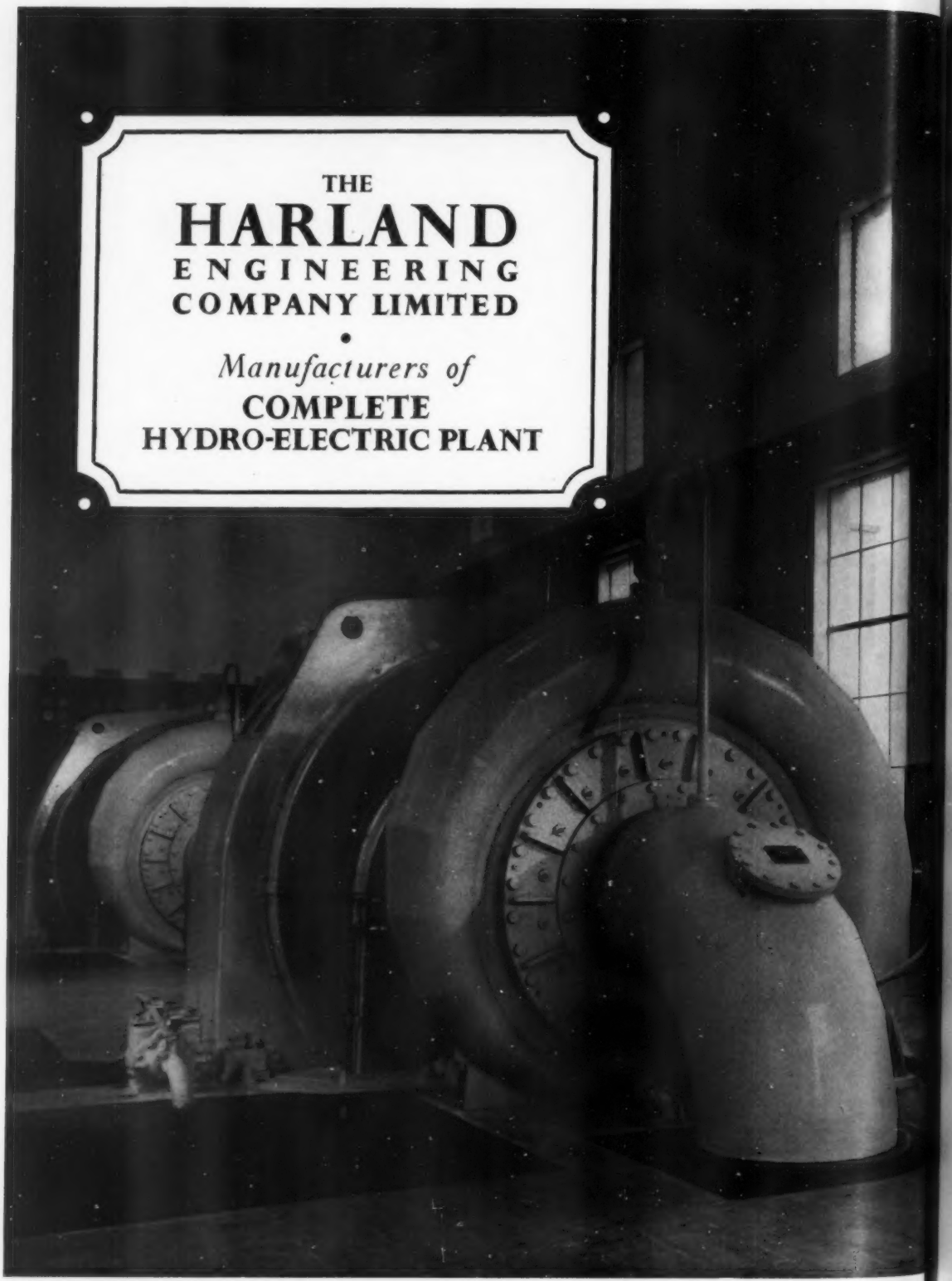

Officially opened on September 26th 1951, the Loch Striven Power Station of the North of Scotland Hydro-Electric Board contains 2 - 4250 B.H.P. "Harland Morgan Smith" Francis Turbines driving 3000 K.W. "Harland" alternators—a fine example of hydraulic and electrical generating plant manufactured under one roof and erected at site by Harland specialist engineers.

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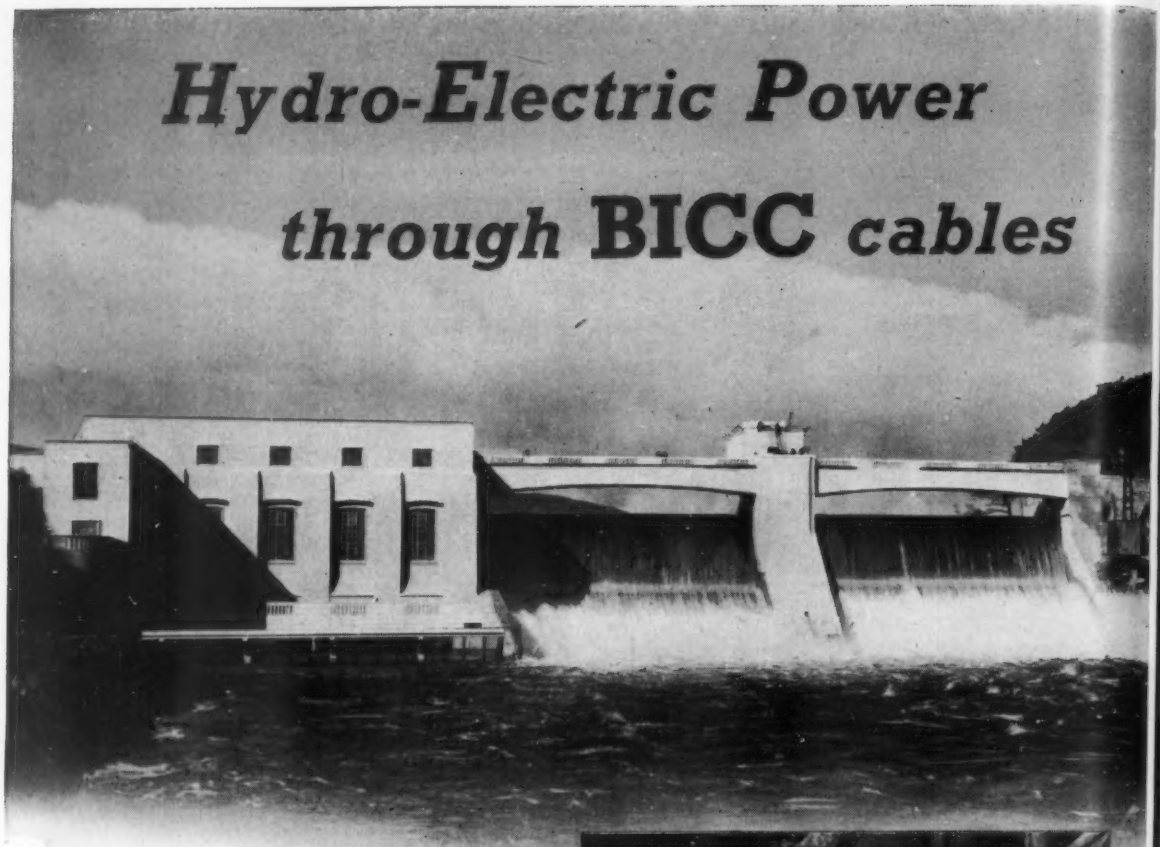
Hydro-Electric Power through **BICC** *cables*

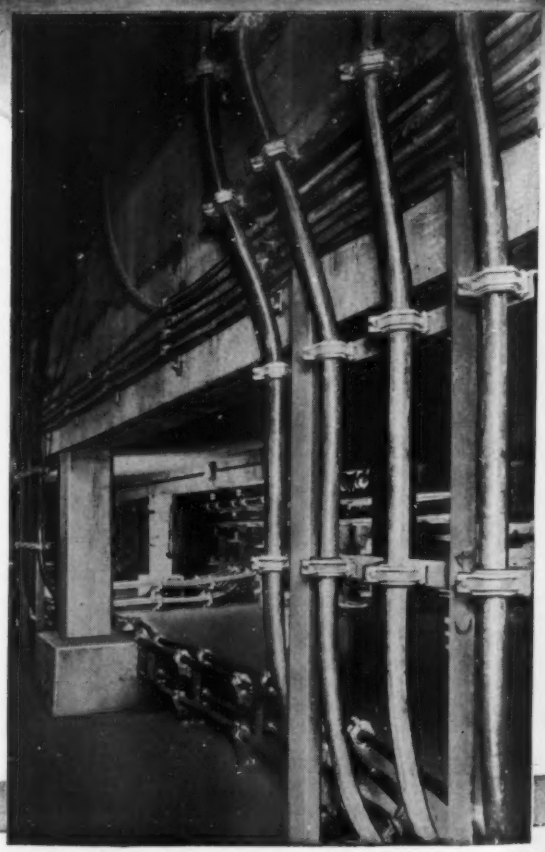


For the two North of Scotland Hydro-Electric Board generating stations at Pitlochry and Clunie, all main power and auxiliary cables were supplied by BICC. This Company also supplied the 3-core 11kV cables and 30-core 7/.029″ auxiliary cables which link the two stations. The installation work was carried out by B.I.C. Construction Company Ltd.—a subsidiary of BICC.

The BICC Organization manufactures, supplies and installs all types of cables for hydro-electric work all over the World.

Above: *General view of Pitlochry Generating Station.*
Right: *Run of 11kV cables from switchgear to transformers at Clunie Generating Station.*

Consultants: Merz & McLellan.



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THE KING

We wish to record our deep sorrow at the passing of our beloved monarch, H.M. King George the Sixth, on February 6. His reign was completely dedicated to the service of his peoples, and the courage with which he continued to fulfil his responsibilities under a burden of increasing ill health was an example to all. The sympathy of our readers will go out to the Queen Mother and the Royal Family in their bereavement, and to our new Queen we offer our affection and loyalty.

Amenities

ALTHOUGH the vast majority of people are greatly in favour of the harnessing of every conceivable source of water power to eke out the world's resources of solid fuel, and to increase the vital electrical energy available for mankind, there have been — and perhaps always will be — a small number of objectors to any proposed hydro-power project. Among them are those concerned with the use of rivers for navigation, for irrigation and for such incidental purposes as the transportation of logs from remote forests to the sawmills near the great cities.

Those concerned with interests of this kind have an obvious and clear-cut case to present when they appear before Commissions of Inquiry into a proposed water-power scheme. In general, their cases are argued with reason, and are not primarily concerned with preventing the scheme taking place, but simply with ensuring that the rights on which their commercial existence depends are not denied or mitigated by the civil works necessary for the generation of electricity. An increasing number of schemes indeed are planned, in these days, as combined all-embracing projects of which these human activities are an integral part.

The other type of objector is one whose case is often incoherently stated. It is frequently based not on logical, commercial or technical grounds, but on prejudice and on ignorance. It is essentially a case concerned with the preservation of amenities, and since no dictionary has yet defined clearly where beauty exists except in the eye of the beholder, it is obviously difficult to convince a man by graphs, diagrams and plans, that an artificial lake will possibly be even more beautiful than the bogs and mud flats which may have existed previously. He will not even agree that a carefully designed, inconspicuous, hydro-electric power station is less obnoxious to his zealous, beauty-preserving eye than a steam power plant with its plume of smoke, its ugly chimneys, its coal dust, and its busy railway trains chugging day and night through the countryside to supply its ever-open jaw with fuel.

It is obvious that no one in his senses would suggest deliberately marring the countryside in, for example, the Scottish Highlands, the Lake District of England, Switzerland, the Pyrenees, or indeed, in any beauty spot anywhere in the world. But those who have visited the Scottish hydro-electric schemes have been unanimously struck by the great care which has been

taken to preserve every aspect of the natural amenities of the district. Pipelines are placed underground wherever possible, and indeed, so has the power station itself in more than one instance; the dams are generally so arranged that their stonework blends with the surrounding rocks, and the power houses nestle almost unseen into their surrounds, built—as they generally are—of stone taken from nearby sources. In Switzerland, where the preservation of the scenery is a vital matter, there exist hundreds of hydro-electric plants which have never been regarded as eyesores.

The control of water, achieved first for hydro-electric reasons, is generally beneficial in other ways; for example, the compensation water which, by agreement, must be passed along the bed of a stream which has been dammed, is often in excess of that which would have been present under drought conditions, as there is a reservoir available to even out the seasonal differences. The amenities may, in fact, be considerably enhanced in this way. The amenity value of a waterfall, for example, may touch on commercial interests, as in the case at Niagara, where agreement has been reached long ago on the amount of water which will be allowed over the falls, so that the tourist attraction can never be diminished.

It should not be difficult, in the light of the experience gained in Switzerland, Sweden, France, Italy, New Zealand and elsewhere, in building hydro-electric plants in situations where the natural beauty of the surroundings reaches nature's highest levels, to prepare a reasoned case, showing that practically never has a hydro-electric plant seriously disturbed the amenity value of the locality. If, for example, the World Power Conference, or perhaps one of the agencies of the United Nations were to undertake the preparation of a copiously illustrated paper or brochure with this end in view, they would undoubtedly be doing a very useful service to the cause of hydro-electric development in general. It would be particularly helpful to those engineers who, harassed as they may legitimately be with the solution of technical problems and with the making of proper provision for the interests concerned with navigation and irrigation, are further worried by the wasp-like buzzing of the fanatical devotees of nature in the untamed and wasteful raw.

United Nations Legal Study

As a step towards encouraging the fuller utilisation of Europe's hydro-electric resources, the United Nations Economic Commission for Europe published on January 17 a study of the legal aspects of the hydro-electric development of rivers and lakes of common interest. The increasing consumption of electric power makes it necessary for the various European countries to proceed with the continuous development of their natural resources, and many of them have in particular been obliged to develop a great part of their hydro-electric potential.

The numerous frontiers between European countries constitute an obstacle to the hydro-electric development of the rivers crossing them (successive waterways) or bounding them (contiguous waterways) and the aim of this study is to simplify the formalities which hamper the development of such rivers in order to promote the best possible utilisation of the total resources. After a detailed analysis of the principles, case law and practice of States in so far as these are known at present, the study draws a distinction between the two following cases:

(1) Where a river flows successively through two territories whose frontiers it crosses, it would seem premature to draw up a standard general convention at the moment. States desiring to do so will find the documentation provided in this study of assistance, and the Secretariat of the Economic Commission for Europe will do all it can to facilitate their task.

(2) As regards contiguous rivers, however, the Committee on Electric Power, in the light of the data provided in this study, has adopted a recommendation containing the various clauses which should appear in international conventions on hydro-electric development. This recommendation includes clauses allowing for the use of the best site for construction, selected on the basis of technical considerations only. It also provides for exemption from import duties and taxes on exports, and for facilities for granting the permits required by the concessionaire for the construction and operation of the works. Finally, it contains special fiscal and customs provisions with regard to the legal position of the common concessionaire. The principle underlying this recommendation, a principle which follows from the preliminary version of the Secretariat's study published for more general circulation, is that works in the construction of which two or more neighbouring states take part should be considered by those states as if they were constructed on their own territory, whatever the site selected.

British Hydromechanics Research Association

The fourth annual report of the British Hydromechanics Research Association records a new stage in the growth of this organisation, for it was in the spring of 1951 that the new laboratory at Harlow was opened by the President, Sir John Anderson. Much time has naturally been occupied in getting the new laboratory into commission, but research on a number of important subjects is in hand. A study is in progress on the mechanism of cavitation erosion, and an interim report is to be issued this year. As part of a long-term scheme to study the performance of centrifugal pumps, a transparent test rig is under construction, consisting of a glass pump casing, a Perspex impeller and suction pipe, and a high-frequency photographic flashlight apparatus. Vortex formation in suction sumps is also being investigated. To enable pipe-friction formulae to be applied with greater precision, an effort is being made to measure the factor of hydraulic roughness directly. Work is also being carried out on surges, on seals, packings and joints, and on reciprocating pumps, and a special investigation is in hand on the performance of the overflow spillways and outlet tunnels for two water-supply reservoirs.

Soviet Developments

According to an article by the Geneva correspondent of *The Times*, detailed information on major constructional projects suggests that these are intended to make a substantial contribution to Soviet economy particularly in the hydro-electric field, inland water transport, and irrigation. The five big hydro-electric

stations planned for the Volga, Don, and Dnieper when complete are expected to raise electrical output by some 22,450 million kWh a year, or more than one-fifth of the present level. They are Tsimlyansk (expected to be in operation this year), Kuibyshev (1955), Stalingrad (1956), Kakhova (1956), and Turkmen Canal (1957). The main civil engineering work on the Volga-Don canal is practically complete. The carrying out of these giant construction works imposes heavy demands on the steel, cement, and heavy electrical engineering industries and also on man-power.

A.I.E.E. Hydro-Electric Session

THE American Institute of Electrical Engineers Committee on Power Generation is planning a session at the summer general meeting to be devoted to a round-table discussion on current power-generation problems. As the session is being arranged by the Hydro-Electric Systems Sub-Committee a large part of the discussion will centre round hydro-electric problems. Questions will be proposed in advance and given some advance circulation so that studied answers may be given at the meeting. Any question pertaining to power generation may be asked. Whether or not members are planning to attend the summer general meeting, questions of general interest to electrical engineers in the power-generating field should be sent to the Committee.

Scottish Power Plant Expansion

AT Dunoon recently, representatives of the North of Scotland Hydro-Electric Board gave Argyll County Council preliminary advance information about the proposed future development of hydro-electric power in the neighbourhood of Loch Awe. The scheme will cost in the region of £10,000,000, and the work will occupy a period of from seven to ten years. Sections concerned are Inverawe, Loch Nant, and Cruachan, and the following are the plans for their development:

It is proposed to regulate the outflow from Loch Awe by the construction of a weir across the river Awe a short distance downstream of its point of outflow from the loch. There would be no raising of the level of the loch which would fluctuate as at present within the range of 116 ft. above sea level in dry weather and 125 ft. in wet. There would not be any interference with the use of steam-boat piers on the loch. A tunnel would convey water from an intake near the weir to a power station on the shore of Loch Etive, a short distance east of the mouth of the river Awe. A flow of compensation water would be available to bring fish up the river Awe and means would be provided to enable them to pass the weir.

A proposed dam at the outlet of Loch Nant would raise its level from 607 to 680 ft. above sea level. Some tributaries flowing into Loch Awe would also be fed into the main tunnel conveying water from Loch Nant to a pipeline feeding a power station near Inverinan on Loch Aweside.

A reservoir with a top water level of 1,280 ft. above sea level would be formed by a dam on the Cruachan burn. Yield from the natural catchment of the burn would be considerably augmented by water brought by diversion aqueducts from areas draining the north and south slope of Cruachan. From the reservoir a tunnel would lead the water to a power station situated at Loch Aweside in the Pass of Brander.

The total capacity of the proposed scheme would be about 55,000 kW and the production of power would be about 165 million kWh per annum.

Model of the Thames

ONE of the largest hydraulic models in the world has been constructed by the Port of London Authority at the Royal Victoria Dock in order to study the flow patterns in the Thames estuary. Each year the Authority has to remove nearly three million cubic yards of silt from the docks and river bed at a cost of between £400,000 and £500,000. This model is designed to assist the P.L.A. engineers to provide some of the answers to the many problems that confront them, and the first of these is to reduce the siltation of the Tilbury tidal basin which at present costs the Authority £75,000 per annum. Further investigations are concerned with pollution, and here again the model will play an indispensable part.

The model is no less than 400 ft. long and has been constructed to a horizontal scale of 1 : 600 and vertical scale of 1 : 60. It operates on a time scale of 1 : 77·46, which means that the tidal period of 12 hr. 25 min. is reproduced in 9 min. 36·3 sec. Tides are simulated by means of reduced air pressure created in a pneumatic displacer by a turbo exhauster, the ebb and flow being reproduced in accordance with a graph drawn on a roll of paper. This graph is scanned by an electronic follower which controls the air pressure and hence the water level in the model.

The model has been moulded in conformity with P.L.A. surveys and has been constructed in cement mortar where the slopes are 40 deg. or more and in natural silica sand of 0·20 mm. mean diameter where the slopes to be simulated are less than 40 deg. River flow is controlled by a V notch in accordance with measurements taken at Teddington weir, the stretch between Teddington and Westminster being represented by a labyrinth having the same tidal characteristics as the river.

A graphic demonstration of tidal effects in the river and estuary were given before a number of engineers last month by the courtesy of the Port of London Authority.

Newfoundland Construction

THE Newfoundland Light and Power Company has under construction two new plants—one of 7,500 h.p. at Cape Broyle for operation this year and one of 7,500 h.p. on the Horse Chops river for 1953. On Bell Island, a diesel unit of 3,580 h.p. is being installed to supply new mining equipment. Last year the company completed its new plant of 13,000 h.p. on the Mobile river and also brought into operation a new unit of 3,350 h.p. in its Tors Cove plant.

The Anglo-Newfoundland Development Co. Ltd. is undertaking the modernisation of its water-power plants on the Exploits river. At Grand Falls, four 4,000 h.p. turbines are being replaced by turbines of 5,500 h.p.; at Bishops Falls, six 1,700 h.p. turbines are to be replaced by 2,700 h.p. units driving 2,250 kVA generators. Work is to begin this year.

The United Towns Electric Co. Ltd. also plans to begin work this year on a 2,000 h.p. plant under 250 ft. head near New Chelsea on the Avalon Peninsula, for operation in 1953.

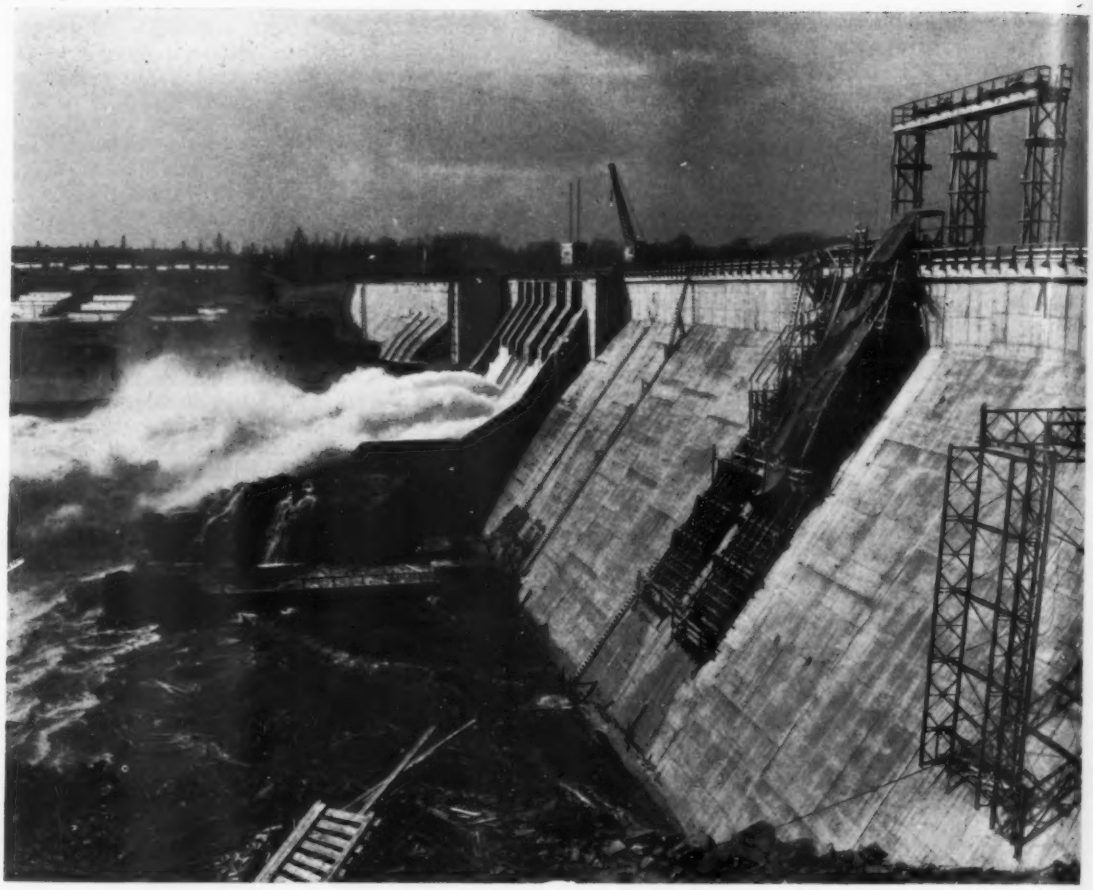


Fig. 1. The Pine Portage generating station and dam, now operating at its full capacity of 60,000 kW

Hydro-Electric Progress in Canada, 1951

We present the text of a year-end summary of water-power development in Canada in 1951 given by the Honourable Robert H. Winters, Minister of Resources and Development, Ottawa.

KEEPING pace with the expansion of general industrial activity throughout Canada, and the consequent need for large additional amounts of electrical power to serve industry and to meet the increasing demand from commercial and domestic sources, construction of power plants proceeded vigorously in 1951. In conformity to the usual pattern of power development in Canada, a large part of this power-plant construction was comprised of hydro-electric installations. There were also a number of thermal units of large capacity brought into operation, and others were under construction. Construction of electrical plants was active in all provinces but in the amount of new hydro-electric capacity coming into operation in 1951, the Province of Quebec was outstanding with a total of 461,700 h.p. One striking feature of new developments under way in 1951 is the number that are located in sparsely settled regions, with the power to be used in the immediate area; this serves to draw attention to the potential value of those undeveloped sites which may appear at present to be so remotely located that development is impractical and uneconomic.

A total of 881,250 h.p. of new hydro-electric capacity was brought into operation in 1951 and, allowing for the dismantling of several old plants, the total installed capacity of waterwheels and turbines in Canada is now listed at 13,340,774 h.p. This repre-

sents about 24 per cent. of known resources. New plants and extensions to existing stations which are under construction for operation in 1952-53 total more than 1,700,000 h.p. and approximately the same amount is under preliminary construction or is definitely planned for operation in 1954-55. Supplemented by the output of new plants, production of electrical power was at a rate of approximately 13 per cent. above 1950; in Canada as a whole, power production facilities were adequate to meet the current demand but little reserve capacity was available.

In the field of power distribution, construction was also very active. New main transmission lines were completed or were under construction in many sections of the country, new transformer and substations were built, and secondary lines were extended. Good progress in rural electrification was achieved, particularly in Ontario, Quebec and Manitoba.

A review of the year's activities in central-station construction and in distribution facilities in each province is given below.

British Columbia

Despite large additions to hydro-electric capacity during the postwar period, power loads have continued to grow so rapidly in British Columbia that plant extensions are being undertaken immediately, much in advance of previously anticipated requirements.

The British Columbia Electric Co. Ltd. completed the installation of a new unit of 70,000 h.p. driving a 62,500 kVA generator in its Buntzen No. 1 plant. This machine replaces seven old units previously listed at 28,200 h.p. and thus increases capacity by 41,800 h.p. The power house was remodelled but no changes were made to the dam and intake structure. The company also has under construction, for operation in 1952, a new development on Wahleach (Jones) lake, about 15 miles east of Chilliwack; the plant will contain one unit of 82,000 h.p. driving a 75,000 kVA generator and will operate under 2,000 ft. head. Orders have been placed for 1953 delivery of equipment comprising a fourth unit of 62,000 h.p. in the Bridge river plant; work on the raising of the La Joie storage dam to provide its full capacity of 570,000 acre-feet will be undertaken in 1952. Preliminary work concerned with the replacement in the Jordan river plant, Vancouver Island, of two older units listed at 16,125 h.p. by one unit of 20,000 h.p., will commence in 1952. During 1951, the transmission and distribution facilities of the company were extended and substation capacity in the Vancouver and Victoria areas was increased; the municipal systems at Hope and Lillooet were purchased from the British Columbia Power Commission and in 1952 will be connected to the company's network by 60 kV lines.

The British Columbia Power Commission brought into operation in April its Whatshan plant of 33,000 h.p. in two units under 710 ft. net head, each driving a 12,500 kVA generator; the project, which has an ultimate capacity of 66,000 h.p., involves a storage dam on the Whatshan river and a 2½ mile tunnel leading to a power house on Lower Arrow lake. The main transmission line to Vernon, 140 miles in length, operates at 138 kV and a second 60 kV line is being built between Vernon and Kamloops. The Commission also had under construction for operation in 1952 a plant of 4,000 h.p. in two units under 130 ft. head at Clowhom Falls at the head of Salmon Arm; the plant has been designed for future expansion to 12,000 h.p. At the John Hart development, Campbell river, two additional units of 28,000 h.p. each will be installed for 1952-53 operation. This will bring the total capacity to 168,000 h.p. A new 132 kV transmission line from the plant to Duncan Bay is under construction and will be completed in 1952. Investigations covering a small development on the Spillimacheen river near Golden were carried out in 1951 but no definite commitment has been made. A number of additions totalling about 4,000 kW were made to the diesel-electric plants of the Commission at various centres.

A project of outstanding importance to the economy of British Columbia came under initial construction in 1951 when the Aluminium Company of Canada began preliminary work on the Nechako-Kitimat development. At the site of the main diversion dam at Nechako Canyon, access roads, clearing, stripping, camp construction, diversion tunnel, and river diversion have been completed and cofferdam construction is nearing completion. At the site of the underground power house on the Kemano river, an access road, a wharf, camps, clearing, and exploratory drifts have been completed and the excavation of access tunnels has begun; work has also begun on the preliminary phases of the tunnel excavation at the inlet end at Tahtsa lake. Clearing of the right-of-way for the transmission line to Kitimat has been commenced. Present plans call for an installation of 420,000 h.p. by early 1954 but tunnel and transmission-line capacity are designed for a total installation of about 1,000,000 h.p. Beyond this, a second tunnel would be required to develop the maximum potential of the development.

The Consolidated Mining and Smelting Company of Canada, Limited, commenced construction in 1951 of its Waneta plant on the Pend d'Oreille river near its junction with the Columbia river. The power house will contain two turbines each rated at 102,500 h.p. under 210 ft. head and driving a 90,000 kVA generator. Operation is scheduled for the spring of 1954 and the power will be transmitted to Trail at 66 kV and tied in with the Kootenay river plants. The company is building a new transmission line from South Slocan to Kimberley which will cross Kootenay lake in a single span with a length slightly in excess of two miles; initial operation will be at 60 kV but it is designed for 170 kV.

Two smaller water-power developments were completed in 1951: 1,000 h.p. by Mastodon Zinc Mines Limited on La Forme Creek about 17 miles north of Revelstoke and 800 h.p. by Western Uranium-Cobalt Mines Limited on Juniper Creek near Skeena Crossing.

The Powell River Company is improving spillway conditions at its Scanlon dam by constructing a diversion channel. In order to supplement its hydro-electric production, a steam turbo-generator of 12,500 kVA is being installed for 1952 operation.

The Northern British Columbia Power Co. Ltd. has installed additional auxiliary diesel generators totalling 3,800 h.p. in its plant at Prince Rupert.

The West Kootenay Power and Light Co. Ltd. is building a 60 kV line from Crawford Bay on the east shore of Kootenay lake to Creston, for the purpose of supplying the town with power from its Kootenay river plant in 1952.

Yukon Territory

The Northwest Territories Power Commission is constructing for operation in 1952 a development of

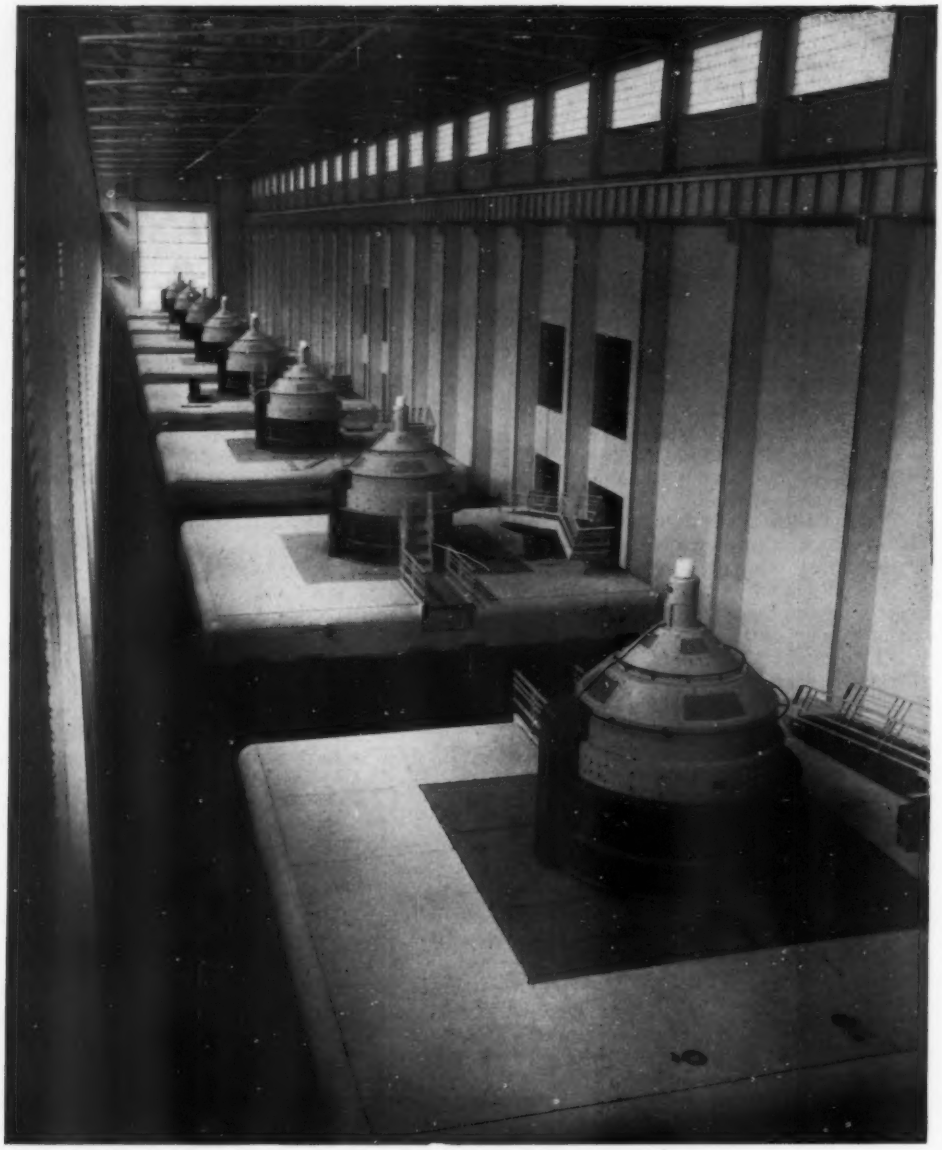


Fig. 2. The eight 60,000 h.p. units of the Des Joachims plant which is now operating at full capacity, the last unit having been placed in service in February, 1951

3,000 h.p. at 110 ft. head on the Mayo river. Work is proceeding on the main dam, power house, permanent buildings, transmission line, and other facilities. The project also includes a storage dam on Mayo lake 20 miles upstream on which work is well advanced. Power will be transmitted at 66 kV to the Keno and Galena Hill area, a distance of about 25 miles. Ultimate capacity of the site is estimated at 8,000 h.p.

The Yukon Hydro Company, which supplies the town of Whitehorse, is planning to add 500 h.p. to its water-power plant on Porter Creek in 1952, bringing capacity to 1,000 h.p.

Alberta

The installed capacity of water-power plants in Alberta was practically doubled during 1951 with the completion by Calgary Power Limited of the Spray Lakes scheme which involves three new plants and an addition to an older plant, in all 100,600 h.p. The water stored in Spray Lakes by the Spray Canyon dam is first passed through the Three Sisters plant of 3,600 h.p., in a single unit under 50 ft. head, which is located at the control dam in Goat Pass; this plant was brought into operation in October. The water is then conveyed by canal, tunnel, and penstock to the main Spray power house which contains a single unit of 62,000 h.p. under 900 ft. head driving a 47,500 kVA generator; this plant also began operation in October. Below the Spray plant, the remaining drop to the Bow river near Canmore is developed in the

Rundle plant with a 23,000 h.p. turbine under 320 ft. head driving a 20,000 kVA generator; operation of this plant was anticipated by late December and it is being listed as in operation in 1951. Owing to the Spray lake storage, the low-water flow of the Bow river was raised sufficiently to allow the economic installation in the Kananaskis plant of a new unit of 12,000 h.p. under 72 ft. head with a generator of 11,250 kVA; the unit is now in operation and the total capacity of the plant is 24,000 h.p.

In order to facilitate distribution of the additional power available from the new plants, Calgary Power Limited completed extensions to its main transmission lines involving 202 miles of 138 kV line and 180 miles of 13 kV to 66 kV. Kanelk Transmission Company, a subsidiary, completed construction of a 132 kV line 120 miles in length from the Barrier plant to the Crowsnest Pass. Extensions were made to rural lines and at the end of 1951 approximately 10,000 farms were being supplied with electric service.

Northland Utilities Limited is considering the development of about 1,500 h.p. at a site on the Heart river near High Prairie; field surveys were made during 1950 but studies have not been completed. The company, by means of diesel plant, serves a number of towns and villages in northern Alberta and at the end of 1951 also was servicing 162 farms.

Canadian Utilities Limited made minor changes to its fuel-power installations and present total capacity is 22,020 kW. In addition to a number of urban centres, the company serves 2,000 farms.

The City of Medicine Hat has begun preliminary construction on a new power house which will contain a 30,000 kW turbo-generator. Operation is planned for November, 1953. This unit will be interconnected with the system of Calgary Power Limited.

Saskatchewan

The Saskatchewan Power Corporation in April completed the installation of a new steam turbo-generator of 15,000 kW capacity in its Estevan plant; total plant capacity is now 22,750 kW. In its Prince Albert plant, a unit of 10,000 kW, which was purchased from the City of Edmonton, is under installation for 1952 operation. At Saskatoon, a new unit of 25,000 kW is on order for early delivery and operation is anticipated in late 1952. The Corporation extended its transmission network by 135 miles of 69 kV line and by 671 miles of 24 kV line. About 3,000 farms were given service in 1951, bringing the total to 7,500.

Manitoba

At the Pine Falls development of the Manitoba Hydro-Electric Board on the lower Winnipeg river, work proceeded on schedule and it was anticipated that two units each of 19,000 h.p. would be brought

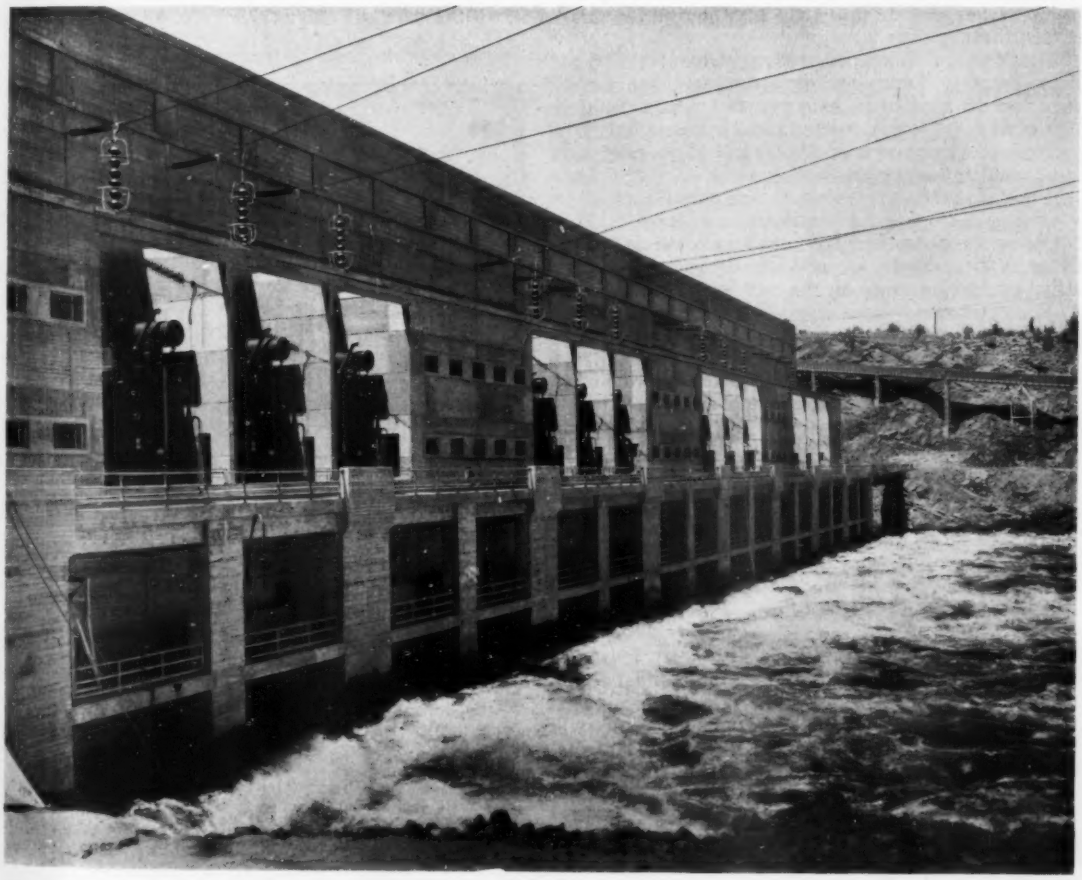


Fig. 3. Downstream view of part of the Des Joachims generating station

into operation during December and that the plant with a total capacity of 114,000 h.p. under 37 ft. head would be completed in 1952. Generators are each rated at 15,500 kVA. The construction of a 115 kV transmission line from the plant to Winnipeg is well advanced.

The Winnipeg Electric Company has under installation in its Seven Sisters plant on the Winnipeg river the sixth and final unit of 37,500 h.p. and operation is scheduled for 1952. This will bring the turbine capacity of the plant to 225,000 h.p. under 66 ft. head and the generator capacity to 195,000 kVA. In order to allow efficient operation of the completed plant, the Pinawa Channel is being closed by rock and gravel fill and the Pinawa power plant of 37,800 h.p., which commenced operation in 1906, is being dismantled.

Construction work has been proceeding on the 7,000 h.p. development on the Laurie river by Sherritt-Gordon Mines Limited to serve the Lynn lake mining field. Additional storage was secured by the construction of a control dam at the outlet of Eager lake. The power house is well advanced and operation of the two-unit plant is expected during the summer of 1952. A 44 mile transmission line is under construction.

The Manitoba Power Commission continued its rural electrification programme, and service was provided to an additional 5,000 farms and to 19 towns and villages. Transmission lines were extended by 15 miles of 110 kV line, 31 miles of 66 kV line, 55 miles of 33 kV line, and 13 miles of 12 kV line; 3,786 miles of distribution lines were built.

The City of Winnipeg, to supplement the peak capacity of its hydro-electric plants, has under construction an auxiliary steam plant of which the first unit of 15,000 kW is expected to be in operation early in 1952. A second unit of 25,000 kW is on order and is planned to be in operation in 1953.

Ontario

Owing to a particularly heavy increase in power demand in southern Ontario, the large current construction programme of the Hydro-Electric Power Commission of Ontario was vigorously expedited.

Hydraulic Power Developments

Des Joachims Generating Station. Seven units at this development were placed in service in 1950 and the eighth (and last) in February, 1951, making the total turbine capacity 496,000 b.h.p. This development is essentially completed.

Chenaux Generating Station. Two units at this station were placed in service in 1950 and the remaining six came in successively in January, February, March, May, July, and September, 1951. The completed station consists of eight units with a total turbine capacity of 168,000 b.h.p.

Otto Holden Generating Station (formerly La Cave). During 1951, authority was obtained to increase the installation at this station from six units to its ultimate capacity of eight. The first units are expected to be in service in January, 1952, and all eight units will be completed before the end of the year. The total turbine capacity will be 272,000 b.h.p. Construction of the station is well advanced. It was expected that the first two units would have been operating in 1951 but high water conditions on the Ottawa river delayed their completion. The 37 mile diversion of the Canadian Pacific Railway was placed in service in September, 1951, and the old line is being salvaged.

Sir Adam Beck—Niagara Generating Station No. 2. Plans are now well advanced for a second generating station at Queenston which will contain seven units totalling 735,000 b.h.p. The intake canal is of special interest. It employs a tunnel with a finished diameter of 45 ft. driven 28,600 ft. through rock and an open canal section approximately 200 ft. wide and 11,800 ft. long. Present schedules call for the operation of four units by the end of 1954 with the balance due in 1955.

Practically all the major equipment has been ordered for the project. Construction camps, roads, and equipment are essentially complete except for the concrete-mixing plants. Two of the five access shafts have been completed to the level of the tunnel and cross-cutting begun. In the canal section, about 50 per cent. of the earth and 20 per cent. of the rock have been removed; about 50 per cent. of the power house excavation will be finished by the end of the year. These total about 3,200,000 cu. yards of excavation.

Steam-Electric Projects

J. Clark Keith Generating Station—Windsor. Initial plans for this station called for two units of 66,000 kW each. Now four units are planned which will provide a total installed capacity of 264,000 kW. Construction of the first stage is nearing completion and the first unit was placed in service on November 16, 1951. The second unit will follow in February, 1952.

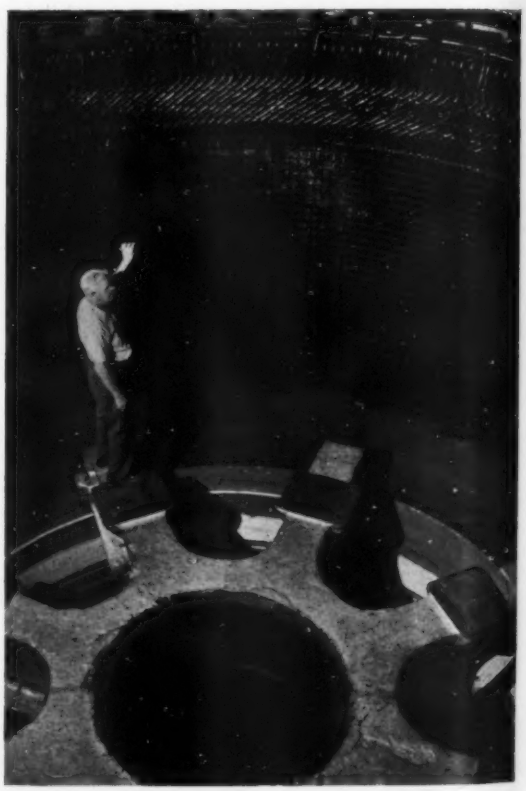


Fig. 4. Inside the stator of one of the ten generators in the Queenston-Chippawa station on the Niagara

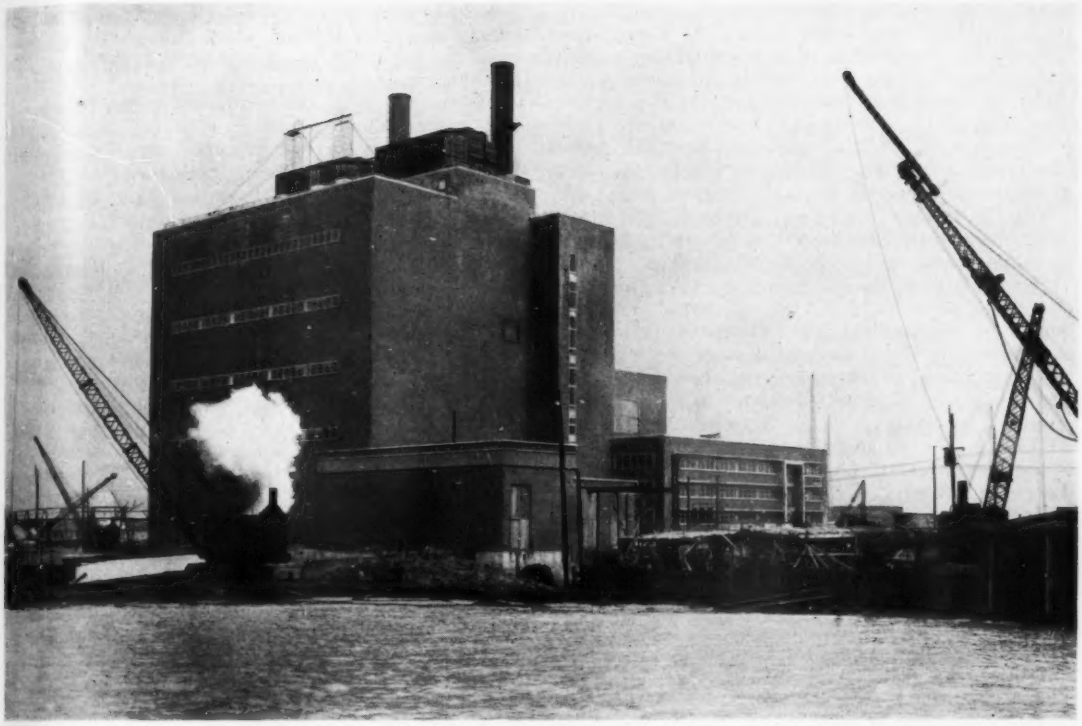


Fig. 5. The J. Clark Keith thermal generating station containing three 60,000 kW English Electric steam turbo-alternators

Designs are progressing on the second stage and construction is already under way. The third unit is scheduled for completion in November, 1952, and the fourth about a year later.

Richard L. Hearn Generating Station — Toronto. This station is being constructed in two stages, each with one 25 cycle, 88,000 kW unit and one 60 cycle, 100,000 kW unit. Provision has been made to convert the 25 cycle units to 60 cycle operation ultimately. The four units will provide a total installed capacity of 376,000 kW with two units operating at 25 cycles and of 400,000 kW after their conversion to 60 cycle operation.

The first 25 cycle unit was placed in service in October, 1951, and the first 60 cycle unit is expected to be operating in December, 1951, completing stage one.

The 25 cycle and the 60 cycle units of stage two are scheduled for November, 1952, and February, 1953, respectively. Plans for this stage are well along. By the end of 1951 all piling and major foundations will have been completed, and the circulating water-line will be finished and structural work begun.

TRANSMISSION LINES, RURAL LINES, AND FARM CUSTOMERS

Extensions to the Commission's transmission and rural lines during 1951 are expected to be as follows:

230 kV lines	198	circuit-miles
115 kV lines	495	circuit-miles
44 to 13 kV lines	383	circuit-miles
Rural lines	3,600	circuit-miles

It is estimated that by the end of 1951 the Commission will be serving approximately 324,000 rural customers. This total includes 122,400 farms.

Aside from the activities of the Commission, the Great Lakes Power Company has under construction for operation in 1952 a development of 15,000 h.p. in two units under 75 ft. head at Scott Falls on the Michipicoten river. Investigations covering a development of 10,000 h.p. at a site above High Falls have been undertaken.

Quebec

Because of the current expansion in industrial activity and the rapid growth in power loads in Quebec, the construction of hydro-electric plants has been accelerated. During 1951, a total of 461,700 h.p. was brought into operation and about 1,500,000 h.p. is under construction for completion by 1955 and earlier. Several old plants have been dismantled.

The largest single addition to plant capacity in Canada during 1951 was that of 223,000 h.p. in four units in the Beauharnois No. 2 power house of the Quebec Hydro-Electric Commission on the St. Lawrence river. The present installed capacity of the power house is 333,000 h.p. and the ultimate capacity, to be reached probably in 1953, is 666,000 h.p. in 12 units under 80 ft. head; dredging operations in the intake canal are being continued to provide the necessary diversion capacity. To meet the mining demands for power in the Temiscamingue-Abitibi district, the Commission began the construction in September of a second plant on the Upper Ottawa river to be located at Rapid II, south of Cadillac. The initial installation, for 1953 operation, will be 16,000 h.p.

in two units and the ultimate capacity is 64,000 h.p. In the field of power distribution, the Commission completed its programme of building additional high-voltage lines between Beauharnois and Montreal, including a second high-tower line over the St. Lawrence river east of Caughnawaga. Other lines are under construction for 1952 completion. New substations have been completed, enlarged or are in the course of erection in Montreal, Renault, Pandora, and Amos.

The Shawinigan Water and Power Company also made an important addition to its generating capacity by adding three units each of 65,000 h.p. to its La Trenche plant on the St. Maurice river. This plant now has a capacity of 325,000 h.p. which may ultimately be increased to 390,000 h.p. Switching and transformer facilities associated with the plant are being completed at Three Rivers. The company has begun work on a project designed to raise the firm output of its plants on the St. Maurice river by about 30,000 h.p. The amount of water available for storage in the Gouin reservoir will be increased by diverting the run-off from 260 square miles of the drainage basins of the upper Megiscane and Susie rivers into the St. Maurice basin. In the distribution field, the company has work under way to raise the capacity of its line from Isle Maligne to Quebec from 187 kV to 230 kV. A new 110 kV line will be built from Sorel to Varennes and a 60 kV line from Quebec to St. Anne de Beaupre. A total of 475 miles of rural lines was built during the year and the company is now serving about 40,000 farms.

The Aluminium Company of Canada has under construction two hydro-electric developments on the Peribonka river. The first one, on which construction was started about a year ago, is located at Chute-du-Diable and will consist of five units having a total turbine capacity of 275,000 h.p. with a head of 110 ft. The second plant, on which work was begun last spring, is located about 13 miles downstream at Chute-a-la-Savanne; it also is designed for five units of a total capacity of 275,000 h.p. under a head of 110 ft. The first unit of the Chute-du-Diable is expected to be in operation in May, 1952, and the first unit of the development of Chute-a-la-Savanne in November, 1952. Both of these plants will tie in with the Saguenay system by means of a double-circuit 154 kV transmission line about 17 miles long, terminating at the present high-tension station at Isle Maligne.

The Price Brothers and Company Limited has had under construction since early June, two hydro-electric developments on the Shipshaw river. The main power plant of 70,000 h.p. will be at Chute-des-Georges and will comprise two units each of 35,000 h.p., to operate under a head of 348 ft. The second power house will use the 47 ft. head remaining between lake Brochet and the forebay of the Chute-aux-Galets plant; the installation will be one unit of 9,000 h.p. The two plants are expected to be in operation by the end of 1953 and the total output will be used at the company's paper mills.

The Manicouagan Power Company commenced, in the early spring of 1951, the construction of a hydro-electric plant near the mouth of the Manicouagan river. The plant is designed for an ultimate capacity of six units of 50,000 h.p. each, under 125 ft. head, but initial installation will be two units only which will be completed and put into operation early in 1953. The plant will provide reserve power for the pulp and paper industry at Baie Comeau and will also supply electricity for secondary industries which are growing upon the North Shore of the river St. Lawrence.

On June 1, 1951, the Northern Quebec Power Co. Ltd. completed the installation of their new 35,000 h.p. unit, bringing the installed capacity of their Quinze power plant up to its ultimate of 85,000 h.p.

The Ste. Marguerite Power Company of Quebec City last October began the construction of a development at "61 Falls," seven miles above the mouth of the Ste. Marguerite river. The plant will have two units each of 8,500 h.p. at 98 ft. head, and is expected to be in operation in May, 1954. The operating head will vary from 78 to 125 ft. The output of this power house will be allocated in the ratio of 75 per cent. to the Iron Ore Company at Seven Islands and of 25 per cent. to the Gulf Pulp and Paper Company at Clark City, Quebec.

The Pembroke Electric Light Co. Ltd. brought into operation in February of this year a new unit of 3,000 h.p. at their Waltham plant on the Black river; a second unit of the same capacity was under installation and expected to be in operation in late December. With these additions, the total capacity of the plant is 12,500 h.p. Their system in Waltham village has been renovated and the voltage raised from 2,300 to 6,900 V.

The Cie Electrique de Mont Laurier completed in January, 1951, the installation of two units of 1,350 h.p. each in its plant on the Lievre river and these units were put on line in March.

The MacLaren Quebec Power Company is contemplating the future construction of a new plant of 45,000 h.p. on the Lievre river at Buckingham. This plant would replace the old grinder-room mill and would consist of three units of 15,000 h.p. each under 60 ft. head.

The City of Megantic contemplates starting construction on a hydro-electric development of 4,450 h.p. on the Chaudiere river at Gayhurst site, 10 miles below the city, in 1952, after land expropriations are completed.

The Southern Canada Power Company built and placed in operation during the year 31 miles of 48 kV transmission line and a further 11 miles are under construction. The company also increased its rural and distribution system mileage for the past year by 136 miles and 21 miles respectively; 67,215 customers are served by the company, of whom 10,765 are farmers.

The Gatineau Power Company has continued the expansion of its distribution facilities; 175 miles of line, mostly in rural areas, were built during the year and the company is now serving 8,300 farms. A 26 kV line was built from Farmer's Rapids to Gatineau Townsite and a 110 kV line from Lachute to Cedars is under construction. Transmission substation capacity was increased by 15,000 kVA and distribution substation capacity by 20,000 kVA.

The Quebec Power Company commenced, in midsummer, the construction of 30 miles of 60 kV transmission line which is expected to be completed in 1952.

Although the City of Sherbrooke acquired last year the hydraulic plant of the Bromptonville Pulp and Paper Company on the St. Francois river at Bromptonville, no conversion from hydraulic to hydro-electric operation was made in the plant this year. This plant

is being operated, under lease, by the Richmond Pulp and Paper Mill.

The Saguenay Electric Company will have built 85 miles of rural lines and converted about 60 miles of lines from 7·2 kV to 12·47 kV by the end of the year. This company is supplying electrical service to 3,635 farmers.

The Quebec Streams Commission successfully maintained regulation of flow for power production and flood control on controlled rivers of the Province of Quebec through its extensive system of storage reservoirs on the St. Maurice, St. Francois, Gatineau, Lievre, Mitis, du Loup, and North rivers, and in lake Kenogami. Preliminary studies of prospective water-power developments have been completed on the Nottaway and Bersimis rivers. To provide more storage on Manouane river watershed, preliminary work was begun on the reconstruction of Dam C at the outlet of lake Chateauvert. The Commission has completed the study of storage-dam projects at the outlet of lake Mistigougueche on the Mitis river and profile and topographic surveys in connection with flood protection on the lower Petite Cascapedia river.

Several plants, dismantled either in 1951 or earlier, have been removed from the list of water-power installations in Quebec. These include the Shawinigan Water and Power Company's No. 1 plant at Shawinigan Falls, 58,500 h.p., its Disraeli plant on the St. Francois river, 4,000 h.p., and the direct-drive plant of the Consolidated Paper Company at Shawinigan Falls, 17,910 h.p.

Nova Scotia

No new hydraulic plants were brought into operation but two plants were under construction for operation in 1952. The Nova Scotia Power Commission made good progress on its Gulch development on the Bear river consisting of one unit of 8,600 h.p. under 225 ft. net head. The Nova Scotia Light and Power Co. Ltd. has under construction at White Rock on the Gaspereau river a development of 4,000 h.p. under 58 ft. head, with completion scheduled for June, 1952; this will replace an older plant of 1,105 h.p.

Important additions were made to fuel-power generating stations during the year and others are under construction. The Nova Scotia Power Commission in June brought into operation the first of two 10,000 kW units at Cantleys Point, Trenton; the second is scheduled for 1952 operation. A diesel plant of 1,000 h.p. is under construction by the Commission at Port Hood. The Nova Scotia Light and Power Co. Ltd. put on line in October a new unit of 20,000 kW in its Halifax plant, and is planning, by 1953, to replace two old units of 4,500 kW by a second 20,000 kW unit. The Seaboard Power Corporation Limited brought into operation in July in its plant at Glace Bay a new unit of 18,750 kW and has on order a similar unit for 1952 delivery.

The Nova Scotia Power Commission completed about 200 miles of new distribution lines in 1951 and has under construction 97 miles of 66 kV line. The Nova Scotia Light and Power Co. Ltd. built 22 miles of 69 kV line and 152 miles of distribution line.

New Brunswick

The New Brunswick Electric Power Commission actively proceeded with the construction of its development of 27,000 h.p. in two units under 75 ft. head on the Tobique river, and operation is scheduled for the spring of 1953. This project includes storage dams on Long and Trousers lakes and on the Sisson branch of the river. The high Sisson dam will provide a future power site of about 5,000 h.p. under a variable head of from 60 to 130 ft. In its fuel-power plant at Grand lake, the Commission brought into operation a new unit of 6,250 kW and a similar unit is under installation for 1952; also, a 15,000 kW unit is on order for 1952 delivery. New 69 kV lines were completed in 1951 between Chatham and Bathurst and between Fredericton and Woodstock; a new line Tobique to Woodstock is under construction. Distribution lines were extended by about 300 miles.

Prince Edward Island

The Maritime Electric Company completed the installation of a unit of 7,500 kW in its steam plant at Charlottetown. The company built 40 miles of 33 kV line and made moderate additions to its distribution system.

Newfoundland

The Newfoundland Light and Power Company completed its new plant of 13,000 h.p. on the Mobile river in February, 1951, and also brought into operation a new unit of 3,350 h.p. in its Tors Cove plant. The company also has under construction two other plants—one of 7,500 h.p. at Cape Broyle for 1952 operation and one of 7,500 h.p. on the Horse Chops river for 1953. On Bell Island, a diesel unit of 3,580 h.p. is being installed to supply new mining equipment. Moderate additions were made to the company's distribution lines during the year.

The Anglo-Newfoundland Development Co. Ltd. is undertaking the modernisation of its water-power plants on the Exploits river. At Grand Falls, four 4,000 h.p. turbines (hydraulic drive) are being replaced by turbines of 5,500 h.p.; at Bishops Falls, six 1,700 h.p. turbines (hydraulic drive) are to be replaced by 2,700 h.p. units driving 2,250 kVA generators, work to begin in 1952.

The United Towns Electric Co. Ltd. plan to begin work in 1952 on a 2,000 h.p. plant under 250 ft. head at tide-water near New Chelsea on the Avalon peninsula, for 1953 operation.

In Labrador, the Iron Ore Company began preliminary construction on a development at Manihek Rapids on Ashuanipi river, a tributary of the Hamilton river. The power plant is designed for an initial installation of 12,000 h.p. in two units under 34 ft. head and of ultimately 24,000 h.p. The project is scheduled for completion in the winter of 1953-54 and will supply electrical energy to Burnt Creek, Knob lake, and the mines in the district.

The above review covers in brief outline the Canadian hydro-electric undertakings which have been built, are under construction, or are more or less definitely planned.

There are in addition other large projects in various parts of Canada which have been under investigation and which undoubtedly will be undertaken within a few years. While a large number of the more attractive sites within convenient distance of present centres of population already have been developed, there is every prospect that further development of Canada's great water-power resources will continue in future years and that the basic power demands of the country's expanding economy for some time to come will be supplied in large measure from hydraulic sources.

Civil Engineering Aspects of Hydro-Electric Development in Scotland

We publish a summary of a paper read in January by Angus A. Fulton, B.Sc., M.I.C.E., before the Institution of Civil Engineers.

ON January 22 Mr. A. A. Fulton, the chief civil and hydraulic engineer to the North of Scotland Hydro-Electric Board, gave a paper entitled "Civil Engineering Aspects of Hydro-Electric Development in Scotland" to a crowded meeting of the Institution of Civil Engineers. The paper was a model of compression, for it formed an admirable and easily digestible summary of an immense amount of work.

Mr. Fulton commenced by stating that insofar as Scottish schemes could be classified, they were characterised by the use of elaborate networks of collecting aqueducts to make the best use of the limited water resources of a country possessing small rivers at moderate heads. In this respect Scottish practice differed from that prevailing on the continent, where high heads were available and where conditions favoured the development of a single large watercourse, such as the Rhine. Referring to this point in the subsequent discussion, Dr. Jaeger said that a tendency was manifesting itself on the continent to follow the Scottish system of collecting aqueducts.

The topography of the Highlands provided an elevated moorland of over 3,000 ft. O.D. on the west and falling gradually to the east and cut by deep valleys, many of which provided good storage basins, but where formed by glacial action they tended to be wide and open, with much overlying drift which was not ideal for dam sites.

Annual rainfall averaged from over 120 in. per annum in the west to as little as 25 in. per annum in the east, the winter and summer run-offs being nearly in the ratio of 2 : 1. The annual diversity was considerable but not excessive. For areas of reasonable size it varied from about 70 per cent. of the long-term average for a dry year to about 150 per cent. for a wet year, the average of three successive dry years being about 80 per cent. of the long-term average.

The virtual absence of limestone made sites for watertight reservoirs easy to find, in spite of the difficulties associated with glacial formation. In certain districts it was difficult to procure good sharp sand or good igneous rock for aggregate.

Two of the major controlling factors in Scottish developments were the preservation of amenities and the maintenance of fish life. The shortage of steel and the difficulty of obtaining certain types of skilled labour had influenced design and construction. The urgency with which construction was required, together with local topographical conditions had offered little scope for such modern departures as thin arched dams, ski-jump spillways, underground power stations and power stations curved in plan, although, as was made clear in the discussion, these developments had been fully considered.

Plant for public supply usually had an installed capacity about 2½ times what would be needed to produce a uniform output all the year round. In any particular instance the average annual output varied

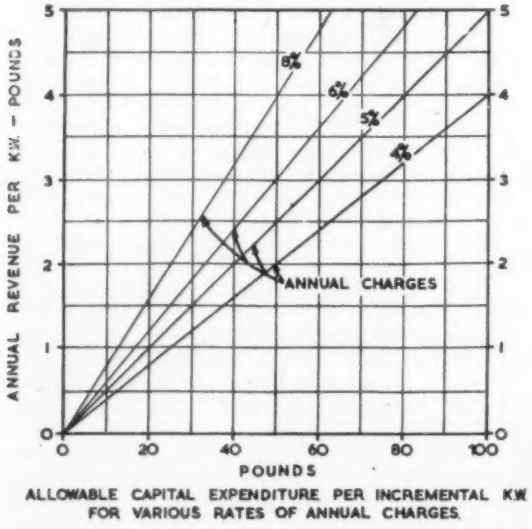


Fig. 1. Capital expenditure on incremental kW

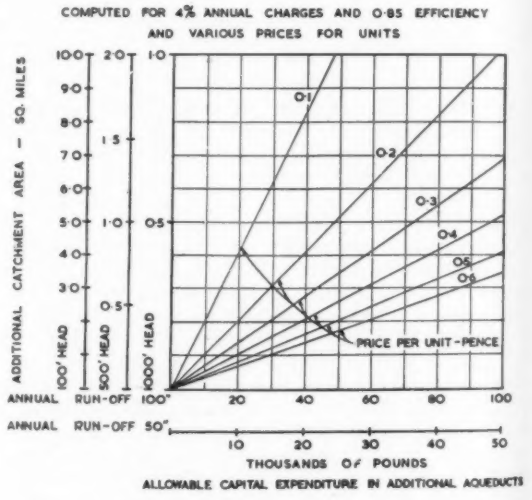


Fig. 2. Capital expenditure on diversion works

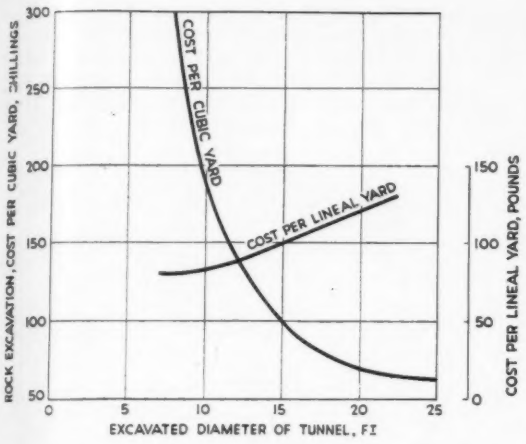

ROCK EXCAVATION, COST PER CUBIC YARD, SHILLINGS
COST PER CUBIC YARD
COST PER LINEAL YARD
COST PER LINEAL YARD, POUNDS
EXCAVATED DIAMETER OF TUNNEL, FT

Fig. 3. Current costs of tunnelling (excluding lining)

little with the capacity installed, but within economic and physical conditions the installed capacity could be varied up or down. Such a proceeding altered the size and cost not only of the generating plant but also of the aqueducts feeding it. If the extra income produced by the sale of the additional kilowatts exceeded the increase in capital charges there was at least an economic justification for increasing the installed capacity. Fig. 1, reproduced from the paper, is a chart of the allowable capital expenditure per incremental kilowatt for various rates of annual charges.

Similarly a decision to collect additional water depended on whether the extra revenue produced by this water was sufficient to pay the increment on the annual charges involved. Fig. 2, also reproduced, reduces this computation to graphical form, based on 4 per cent. annual charges and 85 per cent. efficiency. Thus, for a head of 1,000 ft. and an annual run-off of 100 in. it would be profitable at a price of 0·5d. per unit to bring in an extra 0·4 sq. mile provided the additional expenditure was within £98,000. Owing to the flashy nature of these upper mountain streams it was not usually economic to install an aqueduct of a capacity greater than 4½ times the average flow.

Large-scale impounding was not easy in Scotland, and the present-day cost of impounding was high, as shown in Table I, but in all cases the cost was less than for thermal standby plant.

TABLE I

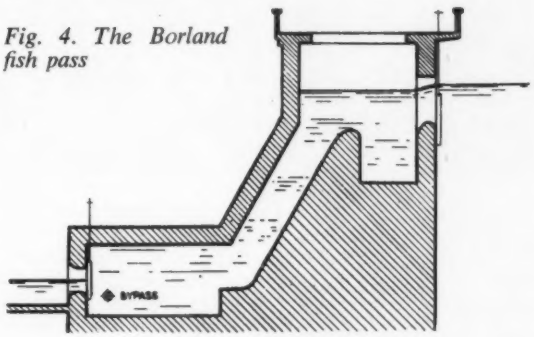
Date	Scheme	Electrical units stored*	Capital cost for impounding per unit stored	Annual cost per unit stored
Pre-1939	Ericht	120 millions	0·3d.	0·012d.
Postwar	Fannich	72 ,,	0·7d.	0·028d.
,,	Mullardoch	78 ,,	8·3d.	0·33d.
,,	Sloy	20 ,,	15·0d.	0·60d.

*Including value through lower stations (if any).

The improved regulation obtained by impounding would alleviate flooding in the lower reaches of rivers, but too great an increase in the summer level of a river might interfere with agricultural drainage. This point was taken up in the discussion by Mr. F. Newhouse, who gave curves for an actual case showing that the interference only obtained for an additional ten days per annum, and these days would not be consecutive. Nevertheless, Mr. Newhouse insisted that each case had to be worked out individually as there was no general rule.

As regards dam construction Mr. Fulton stated that the only departures from such well-tried designs as plain gravity and rock and earth-fill dams were three types of buttress dam, namely, the massive buttress as at Sloy, the round-headed buttress as at Shira, and the diamond-headed buttress as at Errochty. These cut down the mass of concrete required, and in designs possessing a wide base the intensity of loading was lowered. To economise in cement an experiment was to be made on the use of fly ash, and the construction of a dam was contemplated using wet-ground blast-furnace slag. This slag, which had to be ground on site, was mixed with 25 per cent. of Portland cement to make up the normal proportion of cement to aggregate and sand. According to experience in France, where this development was pioneered, heating was reduced by a third, and the concrete was not only of equal strength but was more resistant to aggressive water.

Fig. 4. The Borland fish pass



Another method of saving cement was to abandon concrete in favour of rock-fill dams, and in one case a rock-fill design had been chosen using a watertight upstream membrane with a small amount of fill behind it rather than one with a central concrete core wall and a greater amount of fill. Adequate compaction was vital, particularly with an upstream membrane, and some form of vibrating table seemed to be the most satisfactory medium.

Tunnelling costs were given in the form of a graph, reproduced in Fig. 3, and showed that there was no saving in reducing the diameter below 8 ft. It was still more economical to line a tunnel with concrete rather than use a larger unlined tunnel, having in mind that for equal carrying capacity an unlined tunnel required to be 1·4 times the diameter of a lined tunnel. Rates of excavation, especially since the lighter boring rings had come into use, had improved from 10 cu. yards per week for tunnels in the 10-15 ft. diameter range to 30 cu. yards per week. The costs given in Fig. 3 were thought by Mr. James Williamson and others to be too high, but Mr. Fulton stated that they were based on current contracts.

In dealing with fish passes Mr. Fulton referred to a new type of pass that had been successfully tried out at Leixlip on the river Liffey in Ireland, and was

to be used on several Scottish schemes. It had been devised by Mr. Borland of Kilmarnock, and was diagrammatically illustrated in the drawing reproduced in Fig. 4. The pass operated on a cycle of about two hours, at the beginning of which the lower sluice was open and the water in the lower chamber was at downstream level, the flow of water into the pass over the upper sluice causing an efflux at the bottom which attracted the fish into the lower chamber. After about an hour the lower sluice was closed and the pass allowed to fill, the fish being given a further hour to swim out. The chamber was then drained and the cycle repeated.

In the latter portion of his paper Mr. Fulton gave brief details of a number of major schemes that had been completed or were under construction, and included a table giving a complete schedule of schemes showing their stage of development, capacity and annual output. A number of these schemes have been described in WATER POWER, and a list of references will be found at the end of this summary.

In the discussion Mr. S. B. Donkin and others paid a warm tribute to the late Sir Edward McColl, to whose devoted work the North of Scotland Hydro-Electric Board—and indeed, Scotland—owed so much.

REFERENCES:

The following articles describing Scottish hydro-electric schemes have appeared in WATER POWER:

Tummel-Garry Scheme—		
Clunie dam and tunnel	January-February	1950
Clunie power station	May-June	1950
Pitlochry dam	May	1951
Pitlochry power station	June	1951
Loch Sloy Scheme—		
Preliminary account	May-June	1950
Detailed description	September-October	1950
Royal opening	November-December	1950
Glascarnock, Luichart, Torr Achilty Scheme—		
Loch Fannich tunnel	October	1951
Grudie Bridge power station	November	1951

A series on the Glen Affric scheme is due for publication.

Correspondence

Training of Hydro-Electric Engineers

To the Editor of WATER POWER

I am venturing to send you a few of my thoughts on the training of engineers for hydro-electric work. I have noticed that this subject has been discussed quite frequently on your pages during this past year, but in general with one (and to my mind serious) omission—that of the position of the mechanical engineer in this industry.

Maybe I should explain at this point I am a young mechanical engineer working as a co-ordinator and designer for an important hydro-electric concern. Thus you can see the reason for my interest in this subject; it very vitally influences my own future.

I am fully aware that the civil and electrical groups make up a very large proportion of those people engaged in water-power work, the balance being in main mechanics engaged on equipment maintenance. But at the design stage I believe that the mechanical engineer can play a very important part in tying the two main groups together.

The type of man I refer to is not the mechanical engineer of the machine shop, skilled in production matters and product design, but an unusual sort of jack-of-all-trades who has a working knowledge of concrete design, construction methods and electrical and control fundamentals. This is not a commonplace individual but rather the product of unusually varied experience or specially guided training. What does this kind of man do?

Let me quote a few examples of the type of problem to which I refer:—

Turbine erection often presents quite a problem for the civil engineer as he is usually unfamiliar with the procedures and parts involved.

Turbine and air-conditioning control equipment. Should the electrical man receive sufficient training for him to understand the full function of these items?

Miscellaneous frames, screens, covers, etc. These are often designed by civil engineers and often difficult or expensive to make due to a lack of workshop training.

Embedded piping and drainage sumps. Sometimes difficulties arise due to a layout determined by the civil engineer; sometimes due to the purely mechanically minded piping designer failing to appreciate concreting procedures.

Do I make my point? I have found that there is usually a wide gulf between the civil and electrical men. Their training is very different, their work even more so. But their jobs on a power development often come very close together when it comes to installing mechanical equipment. It is the mechanical engineer who must bridge the gap because he is the one that fully understands the machine and is in the mid-position of being able to understand both the civil and electrical point of view.

My suggestion for training such a mechanical engineer would be as follows:—

The college course taken should be a mechanical one but he should also attend lectures of degree standard in the design of structures (particularly concrete) and the use of surveying instruments. He should not necessarily be expected to attain the degree standard in these subjects, but only to show that he has understood the fundamentals involved. In a similar manner he should be made conversant with electrical circuits, motors, etc., with special reference to control circuits; particularly he should be shown what can be done with magnetic, resistor-pack and electronic control in terms of mechanical action.

For practical experience I would suggest periods spent:—

at machine-shop production work;
at assembly of both heavy and light machinery;
at maintenance of electrically controlled equipment;
as junior engineer on some large construction project, with the opportunity to see concreting and steel erection and the chance to talk to the various foremen at such a site.

Again, I do not suggest that our man should have to obtain top proficiency at any of these jobs or spend a depressingly long time at any of them. But he should stay long enough to learn what can (and even more important what cannot) be done effectively by each group and what sort of problems present the greatest difficulty to them.

After this course I think you would have a man who could turn out to be the key to many problems in the hydro-electric field.

Ontario, Canada. P. PEMBERTON-PIGOTT, B.Sc. (Eng.), P.Eng.

Fig. 1. General view of the Pieve di Cadore dam

Soverzene Generating Station

In this article Dr. Ing. Mario Mainardis, Chief of the Generating Station Department, Società Adriatica di Elettricità, Italy, describes the chief features of the Soverzene power station, which forms part of the Piave-Boite-Vajont scheme.—Part one.

THE Piave-Boite-Vajont hydro-electric scheme utilises to the full the middle course of the river Piave and its tributaries Boite and Vajont, filling the gap between the higher Piave-Ansiei scheme, which reaches from el. 830 m. (2,723 ft.) down to el. 683·50 m. (2,242 ft.) and the lower Piave-S. Croce scheme, starting from el. 386 m. (1,266 ft.) and ending at el. 13·50 m. (44 ft.).

The scheme, as seen in Figs. 1 and 2, includes the three seasonal reservoirs at Pieve di Cadore, on the river Vajont and at Valle di Cadore, for a total storage capacity of approximately 135 million cu. m. (4,670 million cu. ft.), which, together with the Auronzo and Comelico reservoirs (total storage capacity 8 million cu. m.—282·5 million cu. ft.) and the 120 million cu. m. (4,237 million cu. ft.) S. Croce reservoir, allows a complete regulation of the Piave's flow.

The whole scheme consists of the following works:

(1) Pieve di Cadore arch-gravity dam (see Fig. 3) 112 m. (367 ft. 6 in.) high, overall concrete volume 375,000 cu. m. (490,000 cu. yards) creating a reservoir of 64 million cu. m. (2,260 million cu. ft.) capacity.

(2) Valle di Cadore arch dam, on the river Boite, 61 m. (200 ft.) high, creating a 3·8 million cu. m. (134·2 million cu. ft.) reservoir.

(3) Vajont arch dam (still only in project) 202 m. (662 ft. 9 in.) high, creating a 60 million cu. m. (2,119 million cu. ft.) reservoir.

(4) Val Gallina arch dam, 93 m. (305 ft.) high, creating a 6·2 million cu. m. (220 million cu. ft.)

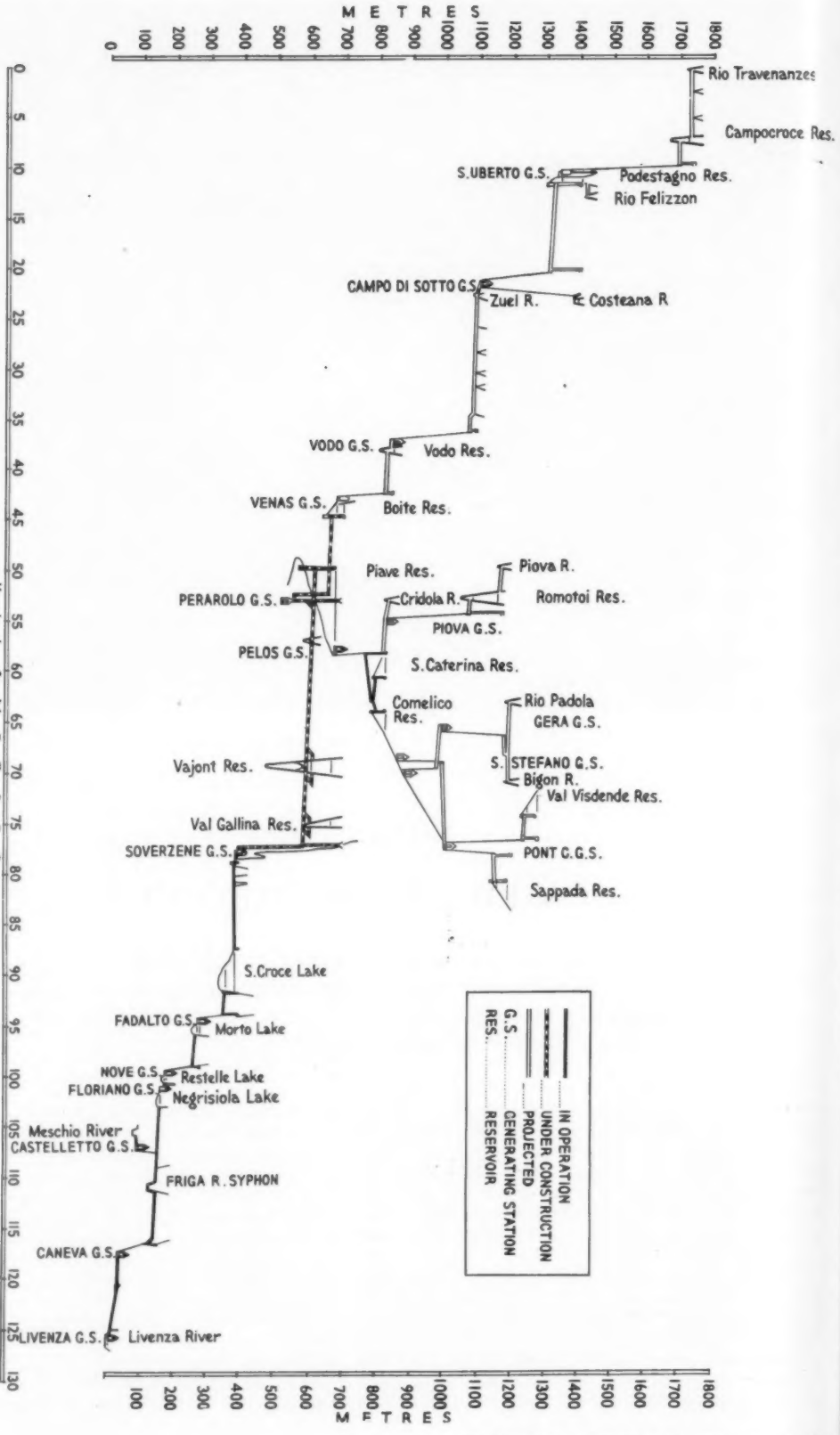


Fig. 2. Longitudinal section of the Piave-Boite-Vajont hydro-electric scheme

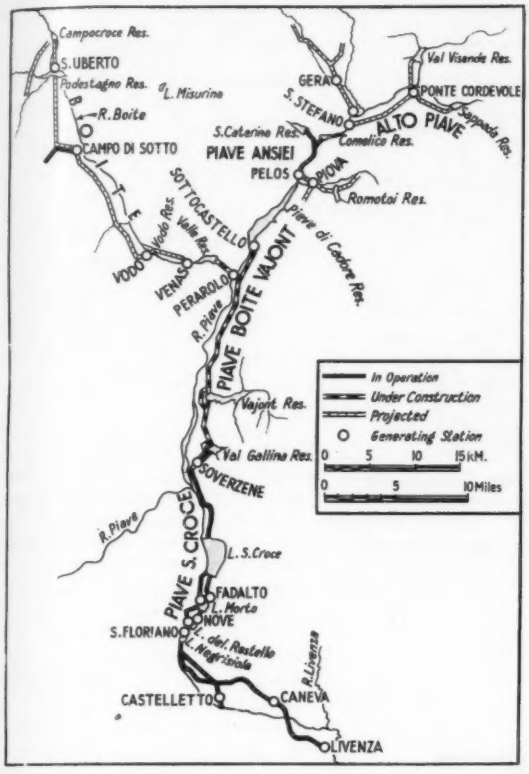


Fig. 3. General layout of the Piave-Boite-Vajont hydro-electric scheme

regulation reservoir; this reservoir will operate chiefly as a large surge tank to eliminate the well-known phenomena of hydraulic instability.

(5) A pressure tunnel, 2·80 m. (9 ft. 2 in.) in diameter, 5·1 km. (3 miles 300 yards) long, connecting the Valle di Cadore to the Pieve da Cadore reservoir.

(6) A pressure tunnel 4·50 to 4·70 m. (14 ft. 9 in. to 15 ft. 5 in.) in diameter, 24·6 km. (15 miles 600 yards) long, connecting the Pieve di Cadore to the Val Gallina reservoir.

(7) Two pressure tunnels 4·50 m. (14 ft. 9 in.) in diameter, 2·55 km. (1 mile 1,100 yards) long, connecting the Val Gallina reservoir to the four surge tanks.

(8) Four prestressed-concrete pipelines.

(9) Soverzene underground generating station.

(10) The tunnel tailrace, provided with sectioning devices by means of which water can be discharged into the canal leading to the S. Croce lake, or into the Piave directly.

The Val Gallina reservoir, besides operating as a surge tank, also enabled the cross-section of the long Pieve di Cadore-Val Gallina pressure tunnel to be reduced to that required for a mean rate of flow of 44 cu. m. per sec. (1,554 cusecs), as the 6 million cu. m. storage capacity of the reservoir is quite sufficient to feed the generating station at full load with 88 cu. m. per sec. during the peak hours.

The total production of the Piave-Ansiei-Boite-Vajont-S. Croce hydro-electric system is approximately 1,550 million kWh per annum, and thanks to the five storage reservoirs, which have a total yearly storage capacity of 255 million kWh, this power is not subject to seasonal variations.

The power is carried, by means of 225, 130 and 60 kV primary networks, into the large distribution area of Società Adriatica di Elettricità, comprising the Venetia, the Romagna and part of the Emilia.

Soverzene Generating Station

Soverzene power station was planned to meet the operating requirements of a "pilot station" in the hydro-electric system of Società Adriatica di Elettricità.

This objective was reached by the following devices:

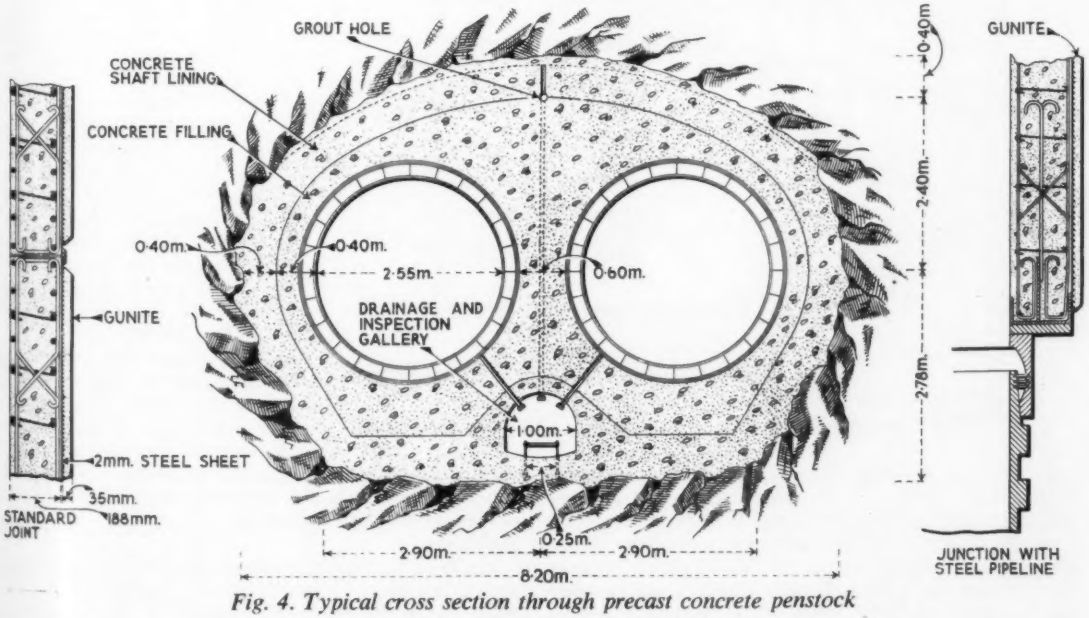
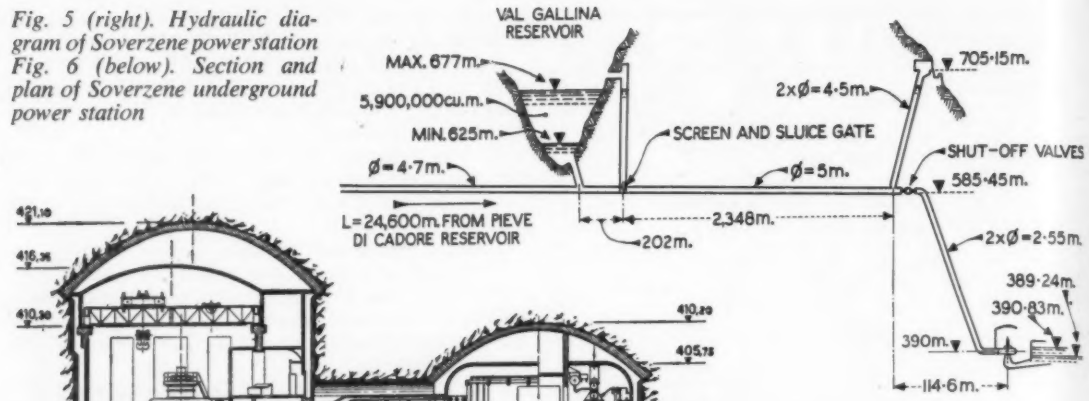
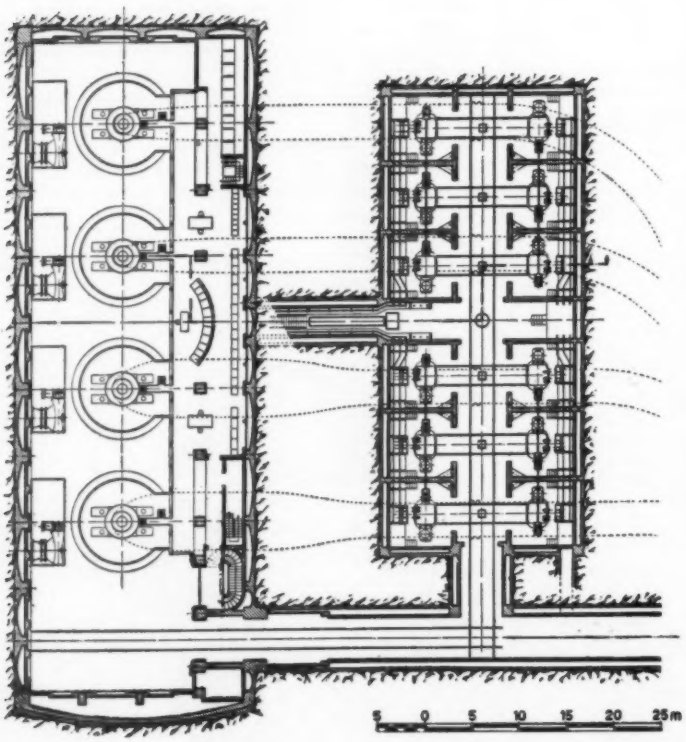


Fig. 4. Typical cross section through precast concrete penstock

Fig. 5 (right). Hydraulic diagram of Soverzene power station
Fig. 6 (below). Section and plan of Soverzene underground power station





(1) By establishing a maximum output sensibly higher than what would correspond to the average utilisation and dividing it between four generating sets.

(2) By placing, immediately upstream of the power station, an adequate reservoir (Val Gallina) to take care of sudden and large flow changes and contain the ensuing pressure oscillations within tolerable limits for hydraulic stability.

(3) By providing the turbine speed governors with speed and acceleration elements of the yielding-link type (a dash-pot) sufficiently flexible to ensure a fast frequency regulation in face of sudden load changes.

(4) By requiring, for the main a.c. generators, a high short-circuit ratio and a high inertia constant, as well as a high-response excitation system in order to reach a satisfactory transient stability.

The underground type of station was chosen not only for the maximum utilisation of the available head, but also because of the substantial saving in capital expenditure. By placing the power station underground it was possible to reduce the length of pipelines to about one-third of the length that would have been necessary for a power station at the surface (230 m.—755 ft. per pipeline, as compared with 640 m.—2,100 ft.) and to use prestressed-concrete pipes, thus achieving a further saving in the unit cost of pipelines as compared with the usual welded-plate pipe (450,000 Lit. per metre run—220 $ per foot—as compared with 650,000 Lit. per metre run —340 $ per foot).

This remarkable advantage in the cost of the pipelines not only made up for the increased cost of the underground as compared with a surface construction, but also allowed a saving of nearly one-third in the overall cost of pipelines and power house (the machines themselves not being included).

Another facility granted by the underground construction was the elimination of relief valves for the hydraulic turbines, as, the length of the pipeline *L*

being approximately equal to the head H, the characteristic constant of the system $\frac{LV}{HgT_r}$ is below the limiting value, 0·10, for good regulation, although the speed of water is as high as 4 m. per sec. and the closing time T_r of the wicket-gate reaches 4 sec.

The four prestressed-concrete pipelines, placed in pairs, in two inclined shafts of elliptical cross section, were built by Società Anonima Cementi Armati Ing. Mantelli (S.A.C.A.I.M.) in the following manner: Each pipe, 4·50 m. (14 ft. 9 in.) long, 2·55 m. (8 ft. 4½ in.) internal diameter and 0·19 m. (7½ in.) thick, was precast off the job in a vertical position. High-frequency vibration was used to consolidate the concrete which was charged into the annulus formed between two cylinders of steel plate, the inner of which was collapsible, while the outer one, which was 2 mm. thick, remained attached to the concrete and became a permanent watertight lining. After 24 days' seasoning, the pipes were armoured around the 2 mm. plate and prestressed with a 5 mm. diameter wire of high tensile strength, this being done in a machine designed for the purpose. After the armouring was completed an outer layer of gunite was applied.

The pipes were then placed in the inclined shaft, and fitted together by butt strap welded joints on the edges of the steel liners. Finally, the space between the pipes and the shaft was filled with vibrated concrete. A section through the penstock is given in Fig. 4.

Tests made on the four pipelines were quite satisfactory; an over-pressure test, made at one and a half times the working pressure, proved the losses to be negligible. At the working pressure the internal compressive stress on the concrete was 8·5 kg. per sq. cm. (121 lb. per sq. in.), and the tensile stress in the steel wire was 7,500 kg. per sq. cm. (106,000 lb. per sq. in.) or half its load capacity. The contribution of the enclosing rock was neglected in considering the stresses at service pressure, but a contribution of 30 per cent. was taken into account in the over-pressure test.

The architectural features of Soverzene power house meet the rules applied in modern underground power stations as regards not only the layout and installation of main and auxiliary equipment, but also hygienic conditions and maintenance of equipment. All the improvements suggested by the building and operating experience collected from Società Adriatica di Elettricità's underground generating stations, *i.e.* Doblari, Plava, Cencenighe, Agordo, Stanga, and from other underground stations built in Italy and abroad* were

* M. Mainardis—"Le Centrali Elettriche" 2nd Ed. Hoepli, Milan, 1951.

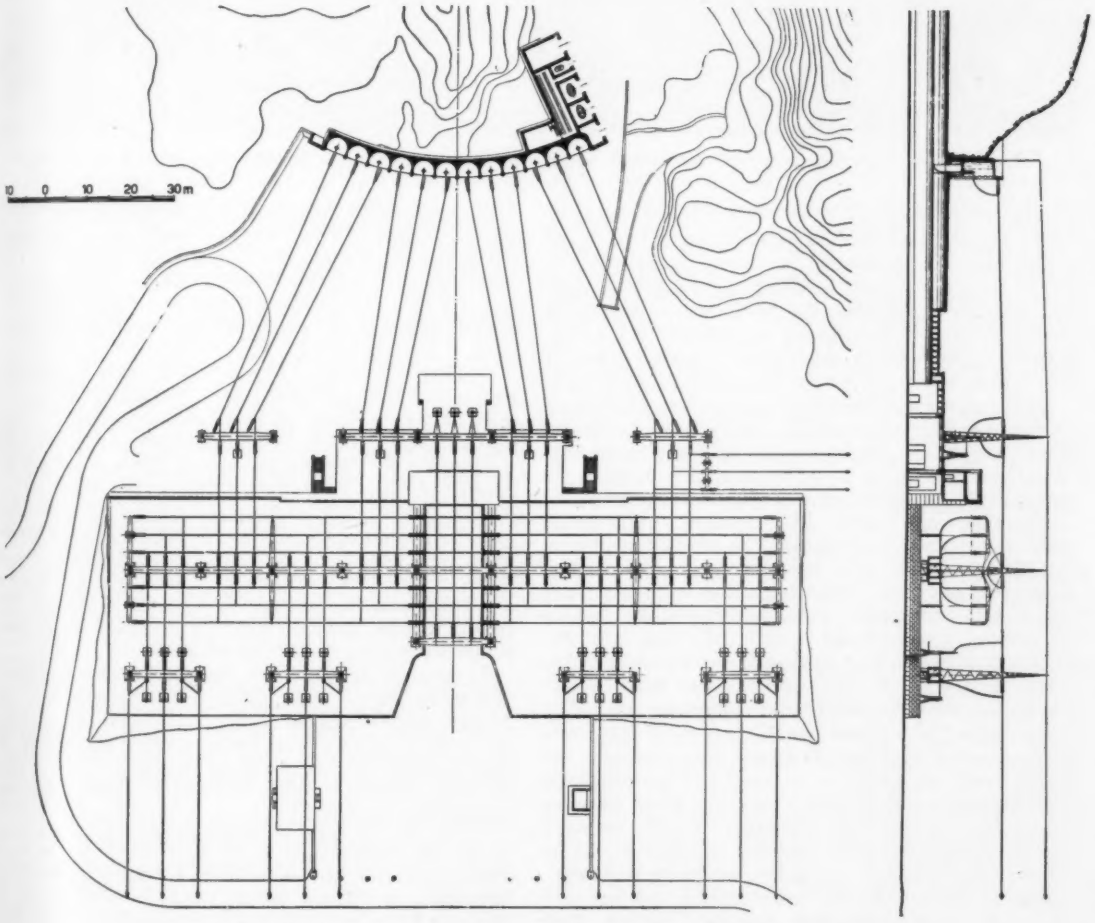


Fig. 7. Elevation and plan of Soverzene surface electrical equipment

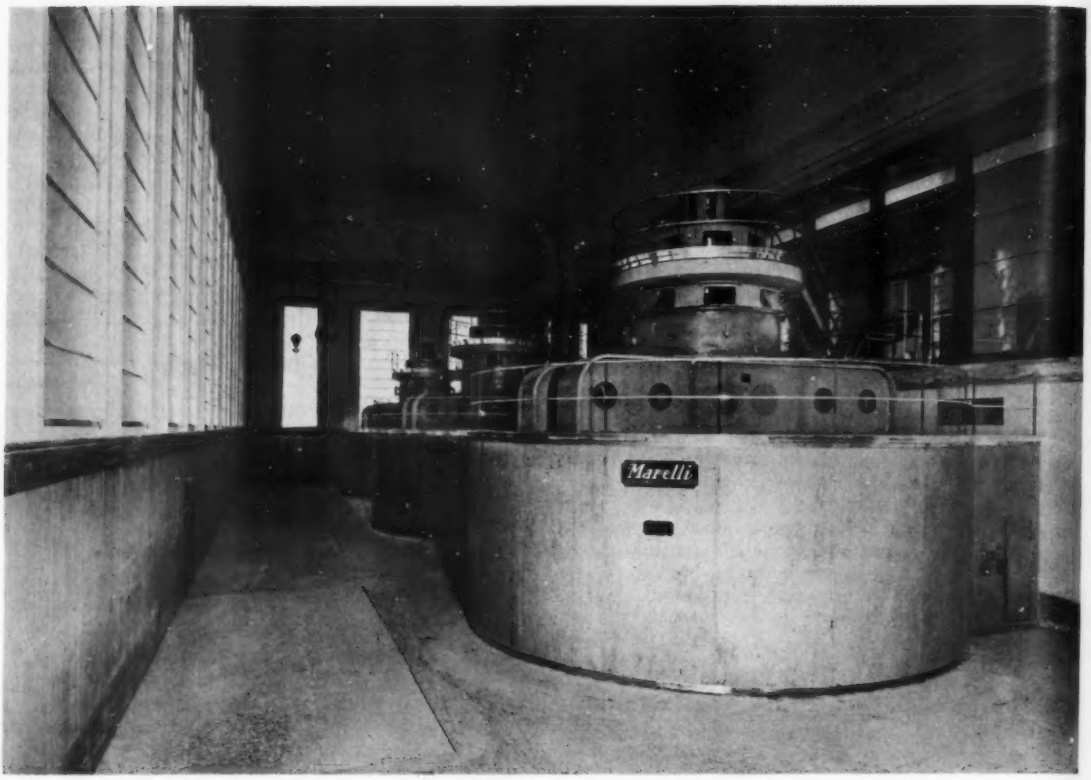


Fig. 8. Interior view of the power house showing three of the 55 MW alternators

applied in this instance to obtain optimum results.

As regards the total generating capacity, it was found advisable, as already mentioned, to make it proportional to a 3,500 hour utilisation per annum. When the scheme is completed, the productive capacity will be round 800 million kWh per annum, and as the total generating capacity of the station was established at 220 MW it was divided into four sets of 55 MW each.

In regard to stability, special devices were adopted in order to minimise surges coming from hydraulic, mechanical or electrical sources, bearing in mind that Soverzene station will have to carry the burden of the frequency regulation and will therefore be subjected to frequent and sudden load changes. In order to minimise the hydraulic surges, the oscillating system, consisting of the surge tanks and the Val Gallina regulating reservoir, were designed to keep the maximum and minimum pressure changes for sudden switchings from full load to no load within tolerable limits, and to reach a satisfactory hydraulic stability even in face of resonance phenomena which might occur for repeated partial switchings on and off.

In order to achieve good frequency regulation modern governors of two types were adopted—the speed and acceleration responsive type and the yielding-link (dashpot) type—having high damping characteristics and stable performance in the presence of transients. To ensure transient stability and to obtain rapid voltage regulation, a short-circuit ratio of not less than 1·20, an inertia constant not less than 6 *s* and a high-response excitation system were required for the main a.c. generators.

In establishing the electrical features for the main a.c. generators it was moreover borne in mind that the Soverzene station will have to feed long 225 kV overhead lines, for which a high self-excitation reactive capacity is required, in order to avoid the well-known self-excitation phenomenon when loading the 225 kV lines.

Single-phase transformer units were preferred chiefly because of transport difficulties. By doing so, moreover, it was possible to keep only one single-phase unit as a spare for the twelve installed units, partially making up for the greater cost of the installation as compared with four three-phase units. The transformer sets are placed near the generating units, so that the reactance of the link is kept down to a minimum; the capacity of the alternators at leading power factor is practically unchanged and losses in the links are substantially reduced, thus making up for the greater capital cost involved in an underground as compared with a surface installation.

In consequence the 10 kV busbars and disconnectors had to be placed underground; whereas the 225 kV busbars and switchgear were placed outdoors, as they are more economical to install and more flexible in their operation. Fig. 8 clearly represents the architectural features of the alternator room and the transformer cubicles.

(To be continued)

Blaw Knox Scraper. A coloured brochure (BK-143/1) describes this firm's BK-80 scraper, which has a capacity of 11 cu. yards and is designed for operation with crawler tractors of 80 h.p.

High-Voltage A.C. and D.C. Power Transmission

J. H. M. Sykes discusses the limiting factors on further increases of voltage for three-phase a.c. transmission schemes, and indicates progress on the only feasible alternative for bringing the power from remote hydro-electric developments to the centres where it is needed—high-voltage direct current.

THE burden of much power-engineering discussion in recent months has veered towards consideration of energy transmission. The gradual using-up of natural resources—both the solid fuel in the whole of a particular country's terrain, and the hydro-electric resources in the vicinity of load centres—has meant that wider and ever wider interconnection has become necessary, to bring the power from where it is generated to where it is needed.

Hydro-electric engineers have also turned their attention to strengthening the remedial measures they alone can provide for overcoming the fundamental difficulty that exists in a thermally powered electricity network—the inability to provide stored energy. They have done this, in many cases, by comprehensive schemes of river and lake regulation, frequently on an annual storage basis; and they have also turned their attention, in other areas, to the increasing of the storage capacity of existing reservoirs, and the turning-in of new streams and rivulets, so as to increase the available water at all times.

In the general field of transportation of energy, progress hitherto has been along the lines of three-phase alternating-current systems of higher and higher voltage.

An increase in voltage, of course, is not the only solution to the problem of increasing power transmission on a given route. It is possible, by installing additional circuits at the highest existing voltage, to transmit almost any amount of power. To do this, however, means that very considerable capital costs have to be incurred. When a distance of over about 250 miles has to be considered, the physical constants of any one of the transmission lines begin to assume values which render electrical operation difficult. For this reason phase-compensation apparatus has to be installed, and consequently the capital costs of the whole scheme are increased not only by the necessity for additional tower-line runs, but also by the considerable expense necessary in the intermediate sub-stations.

Thus the method of increasing transmission capacity by increasing the number of circuits has the disadvantage of high capital costs, of greatly increased maintenance, and of adding a number of possible points of failure at the places where the compensating equipment is installed.

The alternative solution for a.c. transmission schemes is the installation of a minimum number of new circuits at a higher voltage. The distance between points where stability compensation is absolutely necessary may thus be increased; the factor of safety in general is higher; maintenance costs are lowered; and with the very large clearances and the high insulation levels necessary for such voltages as 380 kV, the view has been widely expressed that the vulnerability of the line to atmospheric disturbances, such as lightning, is greatly lessened.

Increase of voltage brings with it difficulties in regard to corona loss, since at voltages above 275 kV this loss may be severe, and may result in an appreciable percentage of lost energy if steps are not taken to mitigate its effects.

The research laboratories at Tidd in the U.S.A., at Chevilly in France, at Upsala in Sweden, and at Leatherhead in Great Britain, have been working on the problem of a.c. corona effects for some years. In general, it can now be proved that by using twin conductors to increase the effective diameter of the charged body, the corona loss can be reduced to a figure which Swedish engineers claim to be as low as 1·8 kW per km. for a 380 kV line, using two 592 sq. mm. conductors. This compares with a figure of 5·7 kW per km. which they arrived at when considering the possibility of using a single conductor of 908 sq. mm. for the same voltage.

M. François Cahen, Directeur Adjoint d'Etudes et Recherches à l'Electricité de France, in the course of some lectures given before the University of London, in March, 1951, stated that the use of "bundle" conductors, *i.e.* two conductors per phase, could reduce the amount of losses to the order of 2·9 kW per km. under average weather conditions. In all corona tests the influence of weather has a very great effect on the losses, which may be as much as twenty times as great under the most adverse conditions of weather, when compared to the lowest values obtained on the same line.

Interference from high-voltage lines may cause severe disturbance to broadcasting and television systems; in the opinion of Mr. Philip Sporn, President of the American Gas & Electric Corporation, the ultimate limits on the use of higher voltage may be attributable to this cause alone. Nevertheless, the Leatherhead experiments at 275 kV using the twin-conductor system proposed for the British Grid, have shown that good television reception is obtainable with an aerial situated no more than 30 ft. from the conductors. Steps taken to mitigate corona difficulties on lines at even higher voltages will, of course, also assist in reducing radio interference.

The use of the "bundle" conductor design also causes an alteration in the physical constants of the line, when compared with a line for equivalent voltage and power flow where a single conductor is used. The capacitance is increased and the inductance is reduced.

This causes the surge impedance of the line to be decreased, and Monsieur Cahen draws the conclusion that "for long-distance power problems in which the line load is of the same order as the surge-impedance load, then the line transmission capacity is increased" (by the use of bundle conductors).

In all parts of the technical world, higher and higher voltage schemes are being planned, and the circuit breakers and transformers they need are being designed. In most cases, these are extrapolations of existing designs; and the air-blast circuit breaker is able to show a considerable advantage over its rivals, the minimum-oil and bulk-oil breakers, by its ability to rise to any desired voltage by the addition of further fully tested units. Great Britain has a 275 kV supergrid in course of construction, with portions designed for ultimate use at 380 kV. France, with 3,400 miles of 225 kV overhead lines coupling her southern hydropower resources with her northern industrial regions, has already built 250 miles of line which can be used later at 380 kV. In America, a Californian line operates already at 287 kV, and a 315 kV scheme is in course of construction. Sweden occupies pride of place, however, for the world's first transmission line for 380 kV is already alive at 220 kV and will be raised to the higher voltage in the next few months. Its 600 mile length and its 300 MVA transmission capacity make it easily the longest and most important transmission line in the world today.

Nevertheless, in spite of these advances in the usage of higher voltage for a.c. transmission to increase transfer capacity and length, there are still disadvantages inherent in the use of alternating current.

First, the impedance of long transmission lines causes operational difficulties which increase as the system becomes more closely interconnected. The stability existing in the tie between synchronous machinery—perhaps the generators of a hydro-electric station at one end of the line, and other synchronous machinery at the other—is endangered at times of transient disturbance, and the system may well fall out of step with consequent failure of supply to large blocks of consumers.

There is no easy and relatively inexpensive method of controlling the flow of fault current on an a.c. network. The use of reactors is expensive and wasteful in energy losses, and is of limited use in any event, since the reactors can seldom keep pace with the growth in system loading.

If two large networks such, for example, as those of France and Great Britain, had to be interconnected with feeders capable of a substantial power flow in either direction, it would be very difficult with an a.c. connection to devise means to limit uncontrolled power flows if the frequency was rapidly fluctuating in one or other of the networks. No one station would be large enough to act as master frequency control.

Again, with an a.c. system, the active materials used are not employed to their best advantage. The insulation throughout the line or cable has to be designed for 1·41 times the nominal working voltage; and it is, of course, obvious that a minimum of three conductors must be used for the transmission of a given load by means of the three-phase a.c. system. Where overhead lines are concerned this means a different and necessarily more expensive type of support, as compared with one in which only two conductors are necessary. In the case of cables, particularly those under the sea, the possibility of transmitting power by the use of a single conductor, with sea return, or at the most two single-core cables, is a factor which obviously must lead to very considerable economy.

These are some of the principal technical reasons for an endeavour to find an alternative to a.c. transmission for major interconnectors. The economic aspect is more difficult to assess, since no d.c. scheme as yet exists, and in any case cost comparisons across international frontiers are often misleading. The paper by Erroll and Forrester before the Institution of Electrical Engineers in 1949 gave some estimated figures showing the capital cost of four systems of transporting 2,000 MW over 370 miles, as related to 1941 figures. They are:—

400 kV a.c. overhead line, £52 million
650 kV d.c. overhead line, £66·5 million
220 kV a.c. cable (underground), £213 million
800 kV d.c. cable, £61 million
(The figures include switching stations and conversion or transforming plant.)

Further figures in the same paper indicated that for the same transmission scheme and allowing for a utilisation time of 8,000 hours a year, the costs of transmission (interest plus losses) amount to only about 0·12 pence per kWh for the 800 kV d.c. cable, and 0·36 pence per kWh for the 220 kV a.c. cable.

Thus, on both technical and economic grounds, engineers are turning, with increasing interest, to consideration of the use of high-voltage direct current, which forms the only alternative in the present state of scientific knowledge. The leaders in this field are the Swedish engineers, who, as will be mentioned later, have in the course of construction the world's first high-voltage direct-current installation.

Interest in this subject is, of course, not confined to the present time. The Thury system, using a voltage of 150 kV, gave reliable service in France for a number of years, until 1937. In 1924, Mr. J. E. Calverley, of The English Electric Co. Ltd., produced, with Mr. Highfield, the "transverter" which could provide direct current at a voltage of 120,000 V, and was a feature of engineering interest at the British Empire Exhibition at Wembley.

The Germans were interested in the scheme, and had some 400 kV equipment ready to go into service during the Second World War, but action by the Western Air Forces prevented its completion. It is understood that much of this equipment has now been erected in the U.S.S.R., and some reports have stated that direct-current transmission has actually taken place in that country for some years, although no confirmatory evidence has been received. Swiss engineers were early experimenters in this field, but do not appear to have pursued it of late years. There have also been experiments in Great Britain. The Electrical Research Association has produced a model equipment on which much study and research has been carried out.

It is in the field of undersea transmission, where there can be no alternative to the use of cable, that high-voltage direct current has first been employed in the Swedish experimental scheme. Here, the case for direct current against alternating current gives an unanswerable victory for d.c. if the cable length exceeds about 25 miles. The reason, of course, is the extensive charging current caused by the capacitance of high-voltage cables when these lengths are exceeded.

Figures given by Mr. Calverley in the 1950 C.I.G.R.E. Conference showed that a 50 c.p.s. cable.

operating at 132 kV, required 2,000 kVA per circuit per mile, while at 400 kV the charging current would become 15,000 kVA per circuit per mile. He also stated that the power stations which would have to supply this charging current would have to be situated fairly close together—about 40 miles apart for 132 kV, 25 miles for 220 kV and 15 miles for 400 kV. Moreover, the operational difficulties which would be introduced by linking two large networks, such for example as those of England and France, by means of a cable of such high impedance as this would render a satisfactory and flexible interchange of energy very difficult to conceive.

It may be useful before describing, in some detail, the world's first high-voltage direct-current link, to reverse the process so far carried out in these notes of describing the disadvantages of a.c. for long-distance, high-power tie lines, and set out briefly the advantages of direct current.

The first and obvious advantage is that two conductors are necessary, as opposed to three for the three-phase a.c. system. Thus, for overhead lines a cheaper type of support can be designed, while for cables the design can be such that two single-core

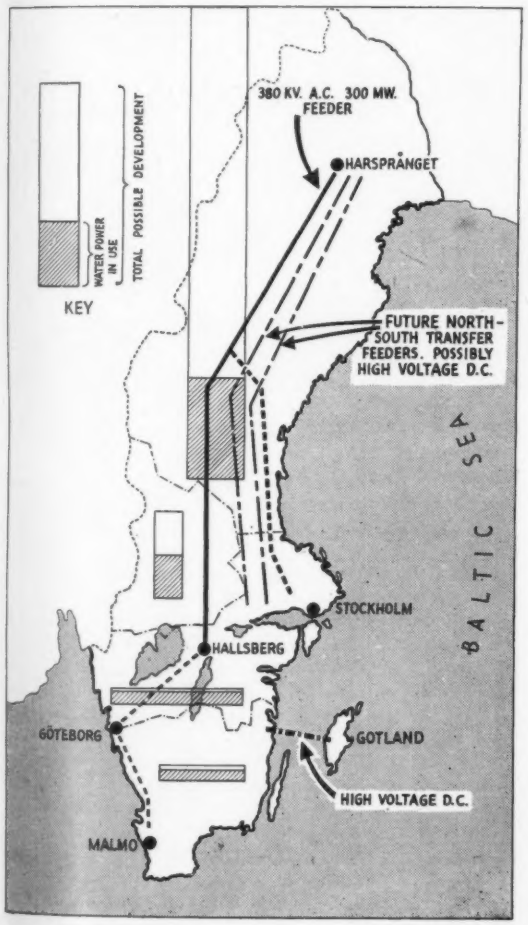


Fig. 1. Sketch map of Sweden showing water-power developments and potentialities and proposed high-voltage d.c. transmission lines

cables can be used without the disadvantages, in regard to electro-magnetic effects on the steel armouring, that would arise if single-core a.c. cables had to be used. Moreover, the insulation can be very much less in radial diameter than in the case of an a.c. cable. This means that the overall diameter of the cable and its cost will be correspondingly less. To prove this point it is worth mentioning at this stage that the 100 kV cable between the mainland of Sweden and the Island of Gotland has an insulation thickness of no more than 7 mm. This compares with an insulation thickness of approximately 13·5 mm. in the case of the British 132 kV high-voltage cables. It should, of course, be remembered that the normal voltage to earth is, in fact, $\frac{132\,\text{kV}}{\sqrt{3}}$, or approximately 76 kV to earth, whereas the 100 kV d.c. cable is 100 kV, *actual value*, to earth.

The next advantage of direct current is that of controllability of power flow. As mentioned above, an a.c. tie-line between two networks or between two large power stations cannot effectively be controlled in regard to instantaneous load swings under heavily varying system-operating conditions. For example, a line outage on one side of a ring-type network can cause a very severe load flow to take place on the corresponding feeder on the other side, and this may well trip in sympathy—an occurrence which has happened more than once on the British Grid system and elsewhere. Further, if one area is extremely heavily loaded and it is necessary to reduce frequency and voltage as a measure of relief (an occurrence all too frequent in Great Britain, France, and elsewhere in some postwar years), the operation of a tie-line between that area and another area which at the same time is not so heavily burdened, becomes extremely difficult. It is impossible to make arrangements whereby a given fixed energy transfer from the lightly loaded area can take place under all conditions to the area where the short-term overloading is occurring.

With a direct-current transmission scheme this difficulty is obviated. The rectification process at one end and the inversion process at the other employs electronic valves with grid control. The extreme flexibility, with instantaneous response to load variation, which is obtainable by electronic means, enables a constant-load-transfer link to be envisaged. In the example mentioned above, the lightly loaded area could transfer to the other section of the network an exact and predetermined amount of energy at all times. If overloading were further to increase in the second area, there would thus be no danger of bringing out both areas, and implicating in a power failure a far larger number of consumers than would be necessitated by purely local loading conditions in the second area.

The disadvantages of high-voltage direct current centre on the as yet untested operation of very high-voltage rectifiers and inverters — particularly the inverters. An inverter is simply a rectifier with its grid control so connected that it interrupts the direct current input in a fashion producing a sine-wave undulating current, and this current is then fed to a transformer. Although manufacturers other than the Swedish makers have tried experiments in rectifier testing, within their own works, on a back-to-back principle, with entire success, the fact remains that before the whole supply of power to a given area can

be entrusted to direct current, the strong conservative feeling among supply authorities will require rectifiers and inverters to be subjected to prolonged testing at high voltages and at full current.

A secondary disadvantage is that the inverter consumes in its operation a considerable amount of reactive power and cannot supply the normal reactive power requirements of an industrial network. A synchronous condenser has to be installed, in addition, for this purpose. This is also the case, however, in long a.c. lines, which are not generally called on to supply the reactive power requirements of the load, as well as their own.

Perhaps the only other disadvantage of direct current is the lack, at the present time, of any type of circuit breaker. The ordinary alternating-current circuit breaker, whether of the bulk-oil, minimum-oil or air-blast design, invariably operates on the principle of utilising a current zero in its method of extinguishing the arc. This feature obviously cannot be applied to a direct-current circuit breaker. It has been suggested that an artificial current zero might be created by the instantaneous discharge of a capacitor at the time when the circuit is to be broken; and it has also been thought that development might take place along the lines of using a large number of breaks in parallel and in series, with suitable arc-control devices, and arrangements to ensure that every break takes its due share of the burden. No manufacturer in the world has yet put forward a design for a direct-current circuit breaker of a capacity and voltage suitable for the many large schemes which have been discussed for utilising this method of transmission. Thus, any scheme contemplated at the present time, at any rate, would have to be confined to a simple load transference usually in one direction only (although a high-voltage d.c. scheme is inherently reversible, even if not necessarily instantaneously and flexibly, as is the case in an a.c. feeder).

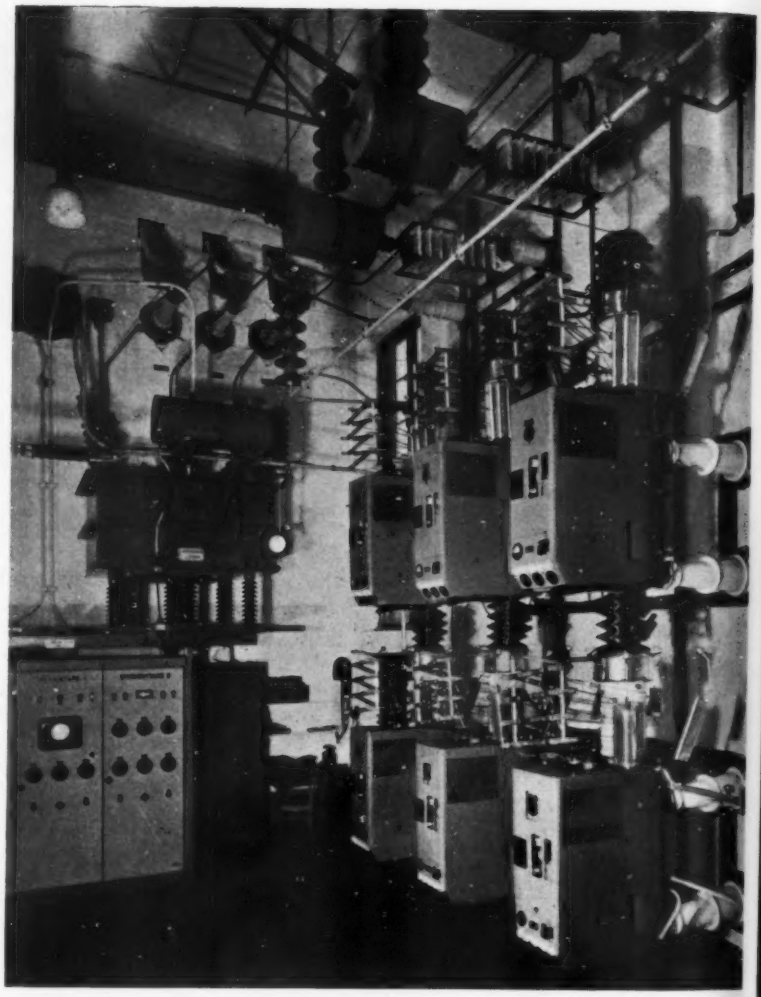


Fig. 2. The 90 kV experimental high-voltage d.c. installation at Trollhättan

The first high-voltage scheme in the world is of special interest to hydro-electric engineers, since it enables the extensive water-power resources of Sweden to be transmitted to the island of Gotland, situated 62½ miles off the eastern coast of Sweden, in the Gulf of Bothnia. The island has no water-power resources and has no coal, and so the very considerable industrial development on Gotland, largely concerned with cement production, has had to rely on thermally generated power supplied by means of imported coal. The importation of coal has become both expensive and difficult, since many of the sources from which the fuel was purchased, for example, Great Britain, are not now able to export the quantities which previously were available.

The sea barrier between the island and the mainland, however, precluded the use of an a.c. link for the reasons indicated earlier in this article. It became a case, therefore, of a d.c. link or no electrical connection at all; and the Swedish engineers, in the pioneer project, were courageously backed by their government, with the result that the apparatus is now under construction. It is hoped that this extremely interesting and novel transmission scheme will be in commission in 1953. The scheme operates at 100 kV to earth, with a load capacity of 200 A, giving a power transfer of 20 MW. A single cable, with sea return, is used.

The 132 kV feed at the mainland station supplies the primaries of two transformer banks, one connected star-delta and the other delta-star, the secondary connections being taken to two separate converter banks each comprising six rectifying valves, the two banks

being connected in series to provide 100 kV across the whole installation. The a.c. connections are brought into the junction points between the cathodes and anodes of the valves, the six valves fed by one transformer being paralleled at top and bottom. This parallel connection is then further joined, by a series link, to the second bank fed from the other transformer.

The type of valve to be used is the only feature of this experiment which is still a matter for final research. The leading Swedish electrical manufacturers, A.S.E.A., in co-operation with the Swedish State Power Board, have experimented for some years on valve design, and have been aided by being able to use a 50-mile transmission line between the State Power Board substation at Trollhättan and the town of Mellerud. Here, at various periods during 1951, a 90 kV d.c. scheme has been in operation transmitting as much as 5·5 MW of commercial load. At the commencement of 1952, a new laboratory in which 400 kV d.c. equipment can be tested, was opened at Trollhätten.

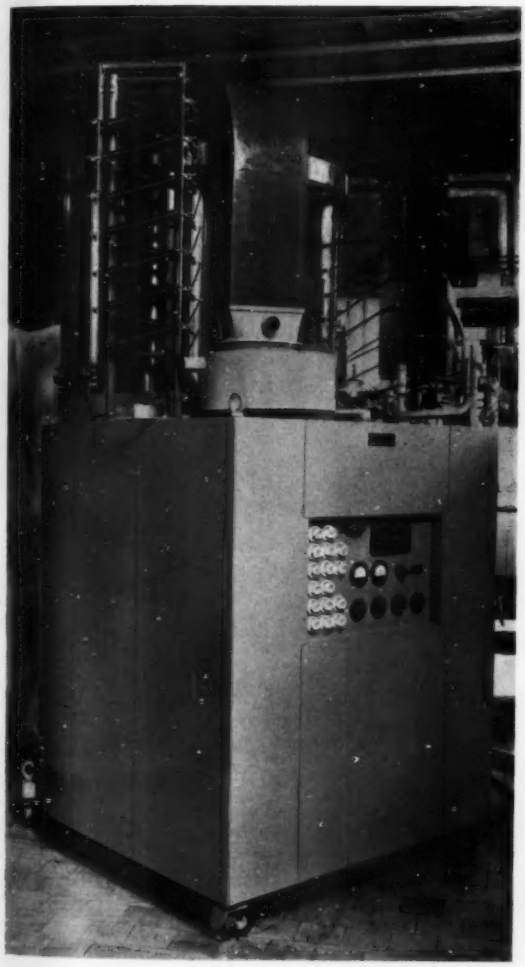


Fig. 3. An experimental valve assembly for 400 kV tests at the new A.S.E.A. laboratory at Trollhättan. It has five anodes in the same tank. Two are designed for operation at high voltage, and three at 200 V full-load current, to test anode life and behaviour

The valves used at Trollhättan comprise a cylindrical steel tank carrying an upper portion of porcelain with a closed-in dome-like top. The anode, which is of iron, has its external connection brought out through a glass seal. Between the anode and the mercury cathode at the bottom of the cylindrical steel vessel there are a number of grids which have the duty of ensuring correct distribution of voltage between anode and cathode. Their connections are also brought out through glass seals to a potentiometer network.

The control grid is situated in the lower portion, and there is also an " animation " electrode, which has the duty of pre-ionising the space below the grid to assist in the starting operation.

Very many experimental valves have been made up and fully tested under all operating conditions at Trollhättan. The 60 kV valves, which are at present in use, in back-to-back testing experiments still in progress, and which are likely to be very close to the design finally approved for use in Gotland, employ a porcelain upper portion, about 2 ft. 6 in. in height, mounted on a mercury seal which couples it to the cylindrical steel tank, which is about 18 in. in diameter and about 2 ft. in length. Two anodes per valve are likely to be employed.

The valve is mounted in a sheet-steel cabinet, containing the mercury pumping device which exhausts the valve continuously into a vacuum receiver. There is also a fan for blowing hot air over the valve when it is out of service, and for cooling when running.

Special transformers have had to be designed to carry the grid-control impulses and the auxiliary supplies for the mercury pump to the valves, which are, of course, at a high voltage to earth. These transformers are of 220/220 V ratio with the secondary winding insulated for the full valve voltage of 100 kV.

In both rectifier and inverter installations, in addition to the six valves used to provide a six-way rectification for one half of the rectifier, there is a seventh valve serving as a bypass and functioning to block its " half rectifier " in the event of a flashover on one of the valve units. This allows current to be transmitted at half voltage through the remaining bank and thus does not entirely shut down the supply. After a predetermined time the grid of the bypass valve has the blocking impulse removed, and allows normal operation to be resumed, assuming the faulty valve has now corrected itself.

Resistances connected from the high-voltage point to earth and used in conjunction with transductors or saturated-core reactors allow of measuring impulses being taken to the control equipment, which is entirely electronic in design. By this aid the phase of the firing impulse to each grid can be controlled. In this way the output, as regards both voltage and current, can also be accurately and smoothly controlled over the whole range of operation, with great simplicity and with an extremely compact array of valves. A choke coil to reduce possible harmonic content of the output completes the major portion of the direct-current equipment at the rectifier end.

The cable employs a copper section of 90 sq. mm. with a single solid conductor. Its capacitance for a 62½ miles route length is no greater than 28 microfarads. Paper insulation, as previously mentioned, of a radial thickness of 7 mm. is used, and the cable is

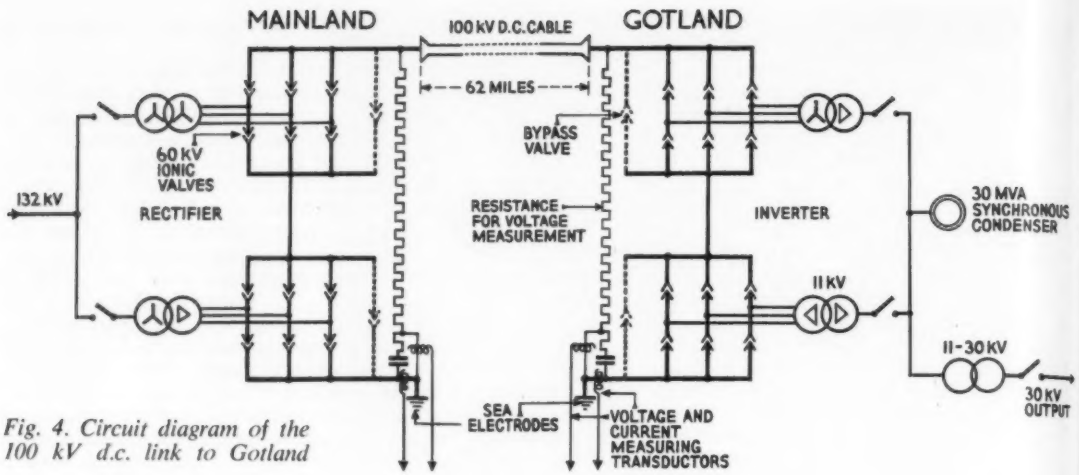


Fig. 4. Circuit diagram of the 100 kV d.c. link to Gotland

double lead sheathed and steel-wire armoured.

The return current is fed from and to the sea by short lengths of open power lines, with a final length of cable guiding it to special electrodes placed at a distance of 10 kilometres from the nearest neighbouring submarine cable. This feature demonstrates one of the advantages of direct current, but it is not likely to be a feature of future schemes, since it is envisaged that the ultimate stage of the Gotland development will be to have two cables, one at 100 kV above earth and the other 100 kV below, thus providing 200 kV between poles, and doubling the present capacity.

The inverter equipment, situated near the town of Visby, on Gotland, comprises an assembly of gear which is almost exactly the same as that used at the rectifier end. The electronic valves are the same and the only additional feature is the synchronous condenser, of 30 MVA capacity, to supply the reactive power requirements on the island. There is also a further transformer stepping the 11 kV three-phase output of the inverter up to 30 kV for use on the island network.

Control of valve operation in the inverter may be carried out, again, entirely by control of the phase of the impulses applied to the control grids. Control of power flow over the link as a whole emanates from a frequency discriminator at the inverter end. This operates in a manner parallel to the functioning of the governor of a hydro-electric generator: the greater the load the greater the tendency for the set to slow down and the frequency to decrease. After this happens the governor takes account of the tendency to run at a lower speed and opens up the guide vanes, so as to allow more energy input to the prime mover. In the case of the d.c. scheme, the frequency discriminator takes account of a tendency to lower frequency due to greater load on the island and "opens up" its own "governor," *i.e.* its control mechanism, which alters the phase displacement of the impulse on the control grids, and so enables more energy to be transmitted.

By means of a two-way short-wave radio link to the mainland, the load-control impulses are applied to the control grids of the rectifier rather than to those of the inverter. Operation on the inverter grids is possible, but is not desirable, since it may cause a heavy demand for reactive power which will throw an undue

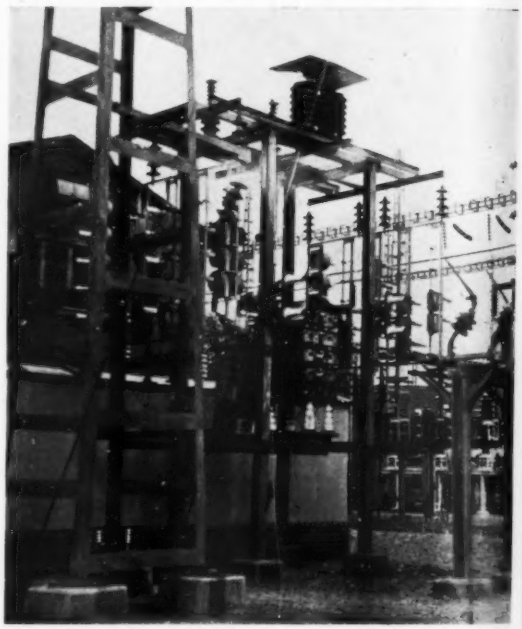


Fig. 5. A view of the 90 kV d.c. experimental equipment, on which a 5·5 MW supply has been provided, to Mellerad, 50 miles away. The capacitors, seen in the centre of the steelwork, are for potential-measurement purposes

burden on the synchronous condenser.

The Swedish authorities calculate that even when the increased cost due to the provision of the special d.c. equipment is allowed for, it will still be less expensive to import hydro-electric power through the d.c. link than to generate electricity in thermal power stations on the island. This is a most valuable pointer to hydro-electric engineers as to the economic possibilities of high voltage d.c. transmission.

Thanks are due to A.S.E.A. Limited and to the Swedish State Power Board for permission to visit their installations, and for the photographs which accompany this article.

Design of Unlined Spiral Casings for Low-Head Stations

In this concluding article the author examines the system of loading on the floor and builds up a complete stress analysis for the structure. The theory is then applied numerically to the design of an actual spiral casing, and includes a consideration of the stress developed in the stay vanes and the calculation of the steel reinforcement.

By Dr. CHARLES JAEGER

2. *Effect of the Horizontal Slab DBC.*

a. TRANSMISSION OF MOMENTS AND DEFLECTIONS IGNORING WATER PRESSURES UNDERNEATH THE FLOOR SLAB

Fig. 6 and Fig. 7 show how the angular rotations and the moments are transmitted from the cylinder *AB* to the slab *DBC*.

Let us assume that a moment $M_1^B = 1$ is acting at the point *B* on the slab *DBC*. This produces a deflection $\tau_{2-3}{}^B$. If the moment acting at *B* is the actual moment $M_1{}^B$, then we should have:

$$M_1{}^B\tau_{2-3}{}^B = \tau^T \ldots\ldots\ldots\ldots (18)$$

This is the first equation of elasticity.

There are two other equations for the elastic angular displacements at points *C* and *D*. At point *C* a moment $M_2{}^C = M_4{}^C$ produces an angular deflection:

$$M_4{}^C\tau_4{}^C = \tau^* = -\frac{1{\cdot}78}{10^6} M_4{}^C \ldots\ldots (19)$$

The same conditions occur at point *D* where:

$$M_5{}^D\tau_5{}^D = \tau^{**} = -\frac{1{\cdot}78}{10^6} M_5{}^D \ldots\ldots (20)$$

The moment $M_1{}^B$ in *B* is divided in two parts: $M_2{}^B$ acts on the slab BC = (length l_2) and $M_3{}^B$ acts on the slab $DB = l_3$. We obviously have:

$$M_1{}^B = M_2{}^B + M_3{}^B \ldots\ldots\ldots (21)$$

We define two coefficients for the transmissions of the moments in *B*:

$$\mu_{1-2} = \frac{M_2{}^B}{M_1{}^B} \text{ and } \mu_{1-3} = \frac{M_3{}^B}{M_1{}^B} \ldots\ldots (22)$$

As no load is applied on the beam *BC*, the moments vary linearly from *B* to *C* and we have:

$$M_2{}^C = \frac{a_2}{l_2 - a_2} M_2{}^B \ldots\ldots\ldots (23)$$

At point *C* we have $M_2{}^C = M_4{}^C$.

The boundary conditions are similar for the beam *DB* and the cylinder *DF*.

Now we have to calculate the transmission factor

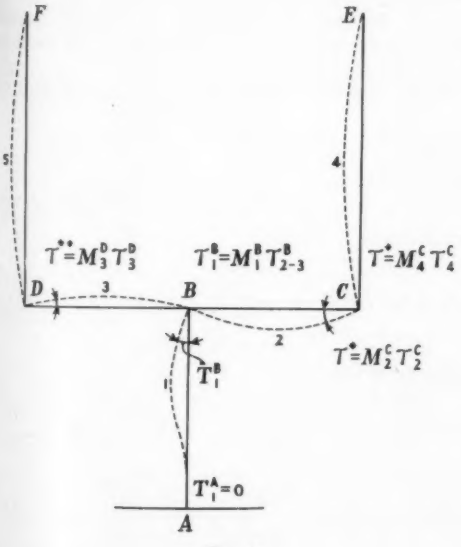


Fig. 6

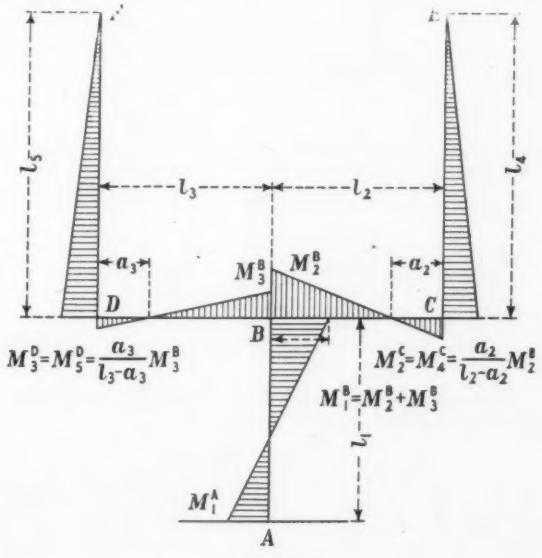


Fig. 7

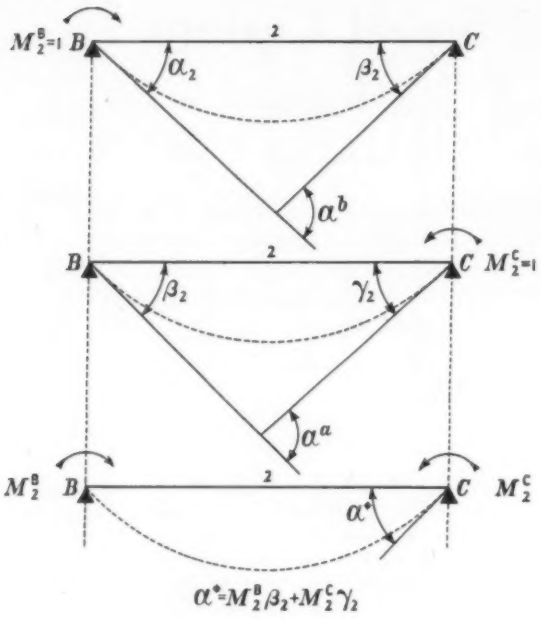


Fig. 8

μ_{1-2} and μ_{1-3}, and the lengths a_2 and a_3 (Fig. 7). This can be done by the following moment-angle relationships.

First we consider the beam *BC* alone (Fig. 8). A moment $M_2^B = 1$ at *B* produces an angular deflection α_2 at *B* and β_2 at *C*.

If the moment $M_2^C = 1$ is acting at *D*, then the angular deflection at *B* is β_2 again (by the theorem of Maxwell) and γ_2 at *C*.

By superimposing these effects for the beam *BC*, we obtain the joint equation at *C* with the cylinder *CE*:

$$M_2^B\beta_2 - M_2^B \frac{a_2}{l_2 - a_2}\gamma_2 = M_4^C \tau_4^C$$

with $$M_4^C = M_2^C = M_2^B \frac{a_2}{l_2 - a_2}$$

This gives $$a_2 = \frac{l_2\beta_2}{\gamma_2 + \beta_2 + \tau_4^c} = \frac{l_2\beta_2}{\alpha_2^a + \tau_4^c} \quad \ldots (24)$$

with $\alpha_2^a = \gamma_2 + \beta_2$

We also shall define $\alpha_2^b = \alpha_2 + \beta_2$.

Similarly we obtain for the beam *DB*:

$$a_3 = \frac{l_3\beta_3}{\alpha_3^a + \tau_5^d} \text{ with } \alpha_3^a = \gamma_3 + \beta_3 \ldots (25)$$

If we consider a non-uniform beam $BC = l_2$ then the total end deflection α^a is (Fig. 9):

$$\alpha^a = \frac{1}{EI}\int_c^l \frac{x\,dx}{I_x}; \quad \alpha^b = \frac{1}{EI}\int_o^l \frac{(l-x)dx}{I_x} \quad \ldots (26)$$

where I_x is the variable moment of inertia of the beam.

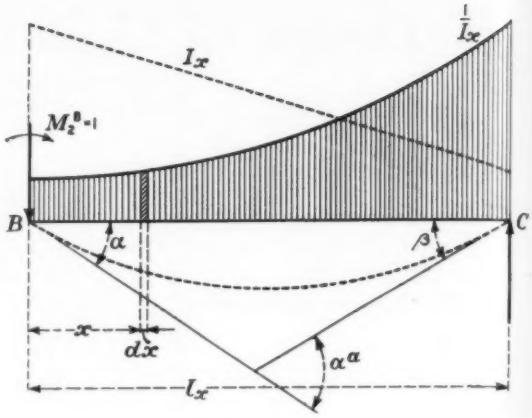


Fig. 9

Also $$\beta = \frac{1}{El^2}\int_o^l \frac{x(l-x)\,dx}{I_x} \quad \ldots (27)$$

The above equations for α^a and β are immediately derived by the "area-moment" method originally due to Mohr.

Angular Deflections at Point B.

The angular deflection T_1^B at the upper end of the vertical cylinder *AB* is equal to the angular deflection of the beam *DBC* at point *B*.

We have already seen that the equation of moments at the joint *B* can be written

$$M_1^B = M_2^B + M_3^B \quad \ldots (21)$$

We can also write

$$T_1^B = M_1^B\tau_{2-3}^B = M_2^B\tau_2^B = M_3^B\tau_3^B \quad \ldots (28)$$

In this equation τ_{2-3}^B is the angular deflection in the beam *DBC* at point *B* if the moment $M_1^B = 1$ is applied at *B*. The angle τ_2^B is the angular variation at the end *B* of the beam *BC* if the moment $M_2^B = 1$ is applied at its end *B*. Similarly τ_3^B is the angular variation at the end *B* of the beam *DB* if the moment $M_3^B = 1$ is applied at its end *B*.

The equation of moments at joint *B* can be written:

$$M_1^B = M_2^B + M_3^B = M_1^B \frac{\tau_{2-3}^B}{\tau_2^B} + M_1^B \frac{\tau_{2-3}^B}{\tau_3^B} \quad \ldots (29)$$

which gives $$\tau_{2-3}^B = \frac{1}{\frac{1}{\tau_2^B} + \frac{1}{\tau_3^B}} \quad \ldots (30)$$

Furthermore we have:

$$\mu_{1-2} = \frac{M_2^B}{M_1^B} = \frac{\tau_{2-3}^B}{\tau_2^B} \text{ and } \mu_{1-3} = \frac{M_3^B}{M_1^B} = \frac{\tau_{2-3}^B}{\tau_3^B} \quad \ldots (31)$$

A moment $M_2^B = 1$ produces the angular deflection

τ_2^B at point B. But this moment produces a moment $M_2^C = \dfrac{a_2}{l_2 - a_2}$ in C and the angular deflection τ_2^B is therefore (Fig. 10):

$$\tau_2^B = \alpha_2 \,.\, 1 - \frac{a_2}{l_2 - a_2} \,.\, \beta_2$$

$$= \alpha^b{}_2 - \beta_2 - \frac{a_2}{l_2 - a_2}\beta_2$$

$$\tau_2^B = \alpha_2{}^b - \frac{l_2}{l_2 - a_2}\beta_2 \ldots\ldots\ldots (32)$$

Similarly

$$\tau_3^B = \alpha_3{}^a - \frac{l^3}{l_3 - a_3}\beta_3 \ldots\ldots\ldots (33)$$

Fig. 10

Numerical Example.

The problem is solved as soon as numerical values can be given for α and β.

The beam *DBC* is represented in plan view in Fig. 11. If $d\varphi = 0{\cdot}222$ and if the thickness of the beam is 2·2 metres, then the moments of inertia I_C at C and I_B at B are:

$$I_C = \frac{1}{12} \,.\, 1 \,.\, 2{\cdot}2^3 = 0{\cdot}89 \text{ metres}^4, \; I_B = 1{\cdot}945 \,.\, 0{\cdot}89$$

$= 1{\cdot}73$ metres^4 and $I_x = 1{\cdot}73 - 0{\cdot}1975x$..... (34)

so that we have for $\alpha_2{}^a$

$$E\alpha_2{}^a = \frac{1}{4{\cdot}25}\int_0^{l_2} \frac{x\,dx}{1{\cdot}73 - 0{\cdot}1975x} = 1{\cdot}882$$

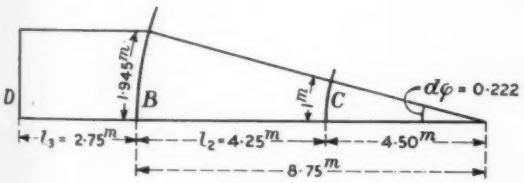


Fig. 11

Similarly

$$E\alpha_2{}^b = \frac{1}{4{\cdot}25}\int_0^{l_2} \frac{(4{\cdot}25 - x)\,dx}{1{\cdot}73 - 0{\cdot}1975x} = 1{\cdot}503;$$

$$E\beta_2 l_2{}^2 = \int_0^{l_2} \frac{x(4{\cdot}25 - x)\,dx}{1{\cdot}73 - 0{\cdot}1975x} \text{ from equation (27)}$$

and $E\beta_2 = 0{\cdot}576$ metre^{-3}

$$\text{and } a_2 = \frac{l_2\beta_2}{\alpha_2{}^a + \tau^*} = 0{\cdot}451 \text{ metres. (From (24).)}$$

Similarly we find for $\alpha_3{}^a$ and β_3 the values: $E\alpha_3{}^a = E\alpha_3{}^b = 0{\cdot}795$ metres^{-3} and $E\beta_3 = 0{\cdot}265$ metre^{-3}, and $a_3 = 0{\cdot}278$ metres.

This gives for $E\tau_2{}^B$ and $E\tau_3{}^B$:

$$E\tau_2{}^B = E\left(\alpha_2{}^b - \frac{l_2}{l_2 - a_2}\beta_2\right) = 0{\cdot}860 \text{ metre}^{-3}$$

(from (32))

$$E\tau_3{}^B = E\left(\alpha_3{}^b - \frac{l_3}{l_3 - a_3}\beta_3\right) = 0{\cdot}50 \text{ metre}^{-3}$$

and $E\tau_{2-3} = 0{\cdot}316$ metre^{-3}. (From (30).)

$$ET_1{}^B = EM_1{}^B\tau_{2-3}{}^B = 0{\cdot}316\, M_1{}^B \text{ tons/metre}^{-2} \ldots (35)$$

Equation of Elasticity.

Finally we have to equate these values of $T_1{}^B$ and $M_1{}^B$ with equation (13).

$$\frac{M_1{}^B}{EI} = -11{\cdot}45 \,.\, 10^{-4} + 138{\cdot}8 \,.\, 10^{-2}(-T_1{}^B) \ldots (13)$$

$$\text{with } I = \frac{s_1{}^3\, R_1\, d\varphi}{12} = \frac{0{\cdot}216 \,.\, 8{\cdot}75 \,.\, 0{\cdot}222}{12} = 0{\cdot}0355.$$

In this last equation we had to introduce $(-T_1{}^B)$, because the direction for positive $T_1{}^B$ values was not the same for the calculation concerning the cylinder *AB* as for the beam *DBC*. The equations give:

$$M_1{}^B = -80{\cdot}7 \text{ metre-tons for } d\varphi = 0{\cdot}222$$

$$\text{and } -T_1{}^B = \frac{0{\cdot}316}{2 \,.\, 10^6}(80{\cdot}7) = \frac{12{\cdot}8}{10^6}$$

which is just under the maximum possible value $M_1{}^B = -81{\cdot}5$ metre-tons which we have already found for $T_1{}^B = 0$. (This moment is negative in the theory of the cylinder, but has to be taken positive in the theory of the beam.)

Finally

$$\mu_{1-2} = \frac{\tau_{2-3}{}^B}{\tau_2{}^B} = 0{\cdot}2875, \; M_2{}^B = 23{\cdot}2 \text{ metre-tons.}$$

and

$$\mu_{1-3} = \frac{\tau_{2-3}{}^B}{\tau_3{}^B} = 0{\cdot}712, \; M_3{}^B = 57{\cdot}5 \text{ metre-tons.}$$

The moment at the end of C of the horizontal floor is

$$M_2{}^C = \frac{a_2}{l_2 - a_2} M_2{}^B = 2{\cdot}82 \text{ metre-tons.}$$

The moments along the cylinder *AB* are given by the formula

$$M = EI\frac{d^2y}{dx^2} \text{ where}$$

$$\frac{d^2y}{dx^2} = \frac{u^2}{s^2}\left\{2e^{-\frac{ux}{s}}\left(A_1 \sin\frac{ux}{s} - A_2\cos\frac{ux}{s}\right)\right.$$

$$\left. + 2e^{\frac{ux}{s}}\left(-A_3\sin\frac{ux}{s} + A_4\cos\frac{ux}{s}\right)\right\}$$

For $x = 0$, $M^A = 45{\cdot}5$ metre-tons.
For $x = l$, $M^B = -80{\cdot}7$ metre-tons.

The curves of moments are represented in Fig. 12. The horizontal displacements y of the cylinder AB are given by the formula:

$$y = \frac{pR^2}{E_1 s} + e^{\frac{-ux}{s}}\left(A_1 \cos\frac{ux}{s} + A_2 \sin\frac{ux}{s}\right) + e^{\frac{ux}{s}}\left(A_3 \cos\frac{ux}{s} + A_4 \sin\frac{ux}{s}\right)$$

The elastic deformation curve is represented on Fig. 13.

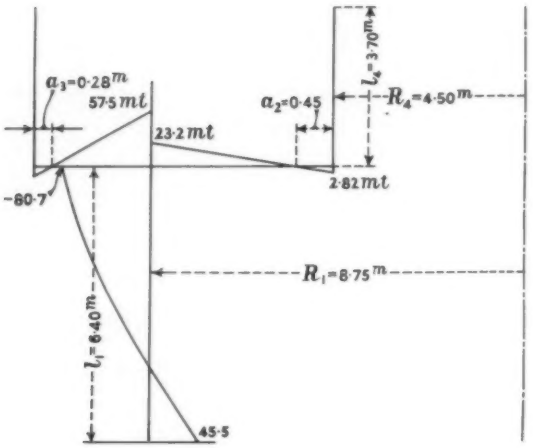
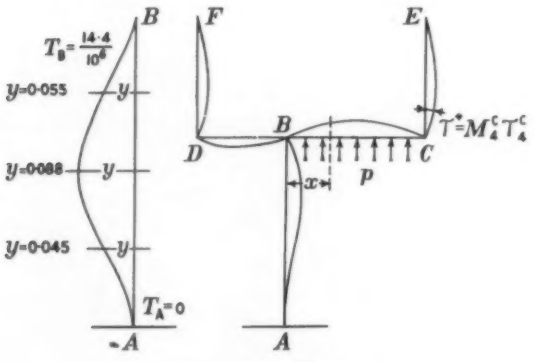


Fig. 12

b. CONSIDERATION OF WATER PRESSURE ACTING ON THE PART *BC* OF THE MAIN FLOOR SLAB. *BC* IS FIRST CONSIDERED PIN-POINTED, AND THEN THE JOINT EQUATIONS AT *B* AND *C* GIVE THE DEFORMATION OF THE WHOLE FRAME

Let us now consider the second part of the problem, when a vertical uniform load $p = 20{\cdot}5$ tons/metre is applied to the horizontal beam *BC* (Fig. 14). If we consider an angle in the centre $d\varphi = 0{\cdot}222$, then the moment of inertia of the beam *BC* is (Fig. 11):



Figs. 13 and 14

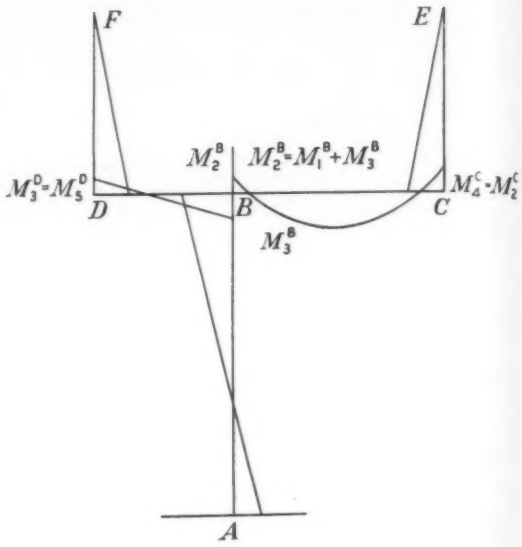


Fig. 15

$$Ix = 1{\cdot}73 - 0{\cdot}1975x \;.\; m_4 \quad \ldots\ldots\ldots\ldots \quad (34)$$

The load p_x varies with the width of the beam and therefore also varies linearly with x. (Fig. 15.)

We have: $p_x = 39{\cdot}9 - 4{\cdot}56x$ with $p_B = 39{\cdot}9$ tons/metre at B and $p_C = 20{\cdot}5$ tons/metre at C.

The total vertical load on the beam *BC* is:

$$P = \int_o^{l_2} p_x dx = 128{\cdot}4 \text{ tons}$$

and the moments in the simply supported beam *BC* are given by:

$$M_{ox} = 71{\cdot}05x - 19{\cdot}96x^2 + 0{\cdot}76x^3 \text{ tons/metre} \ldots \quad (36)$$

(See Fig. 16.)

In the simply supported beam *BC*, the angular deflections at the beam ends *B* and *C* are:

$$E\alpha_B' = \frac{1}{l_2}\int_o^{l_2} \frac{M}{I}(l-x)\,dx = 72{\cdot}95 \text{ tons/metre}^2. \quad (37)$$

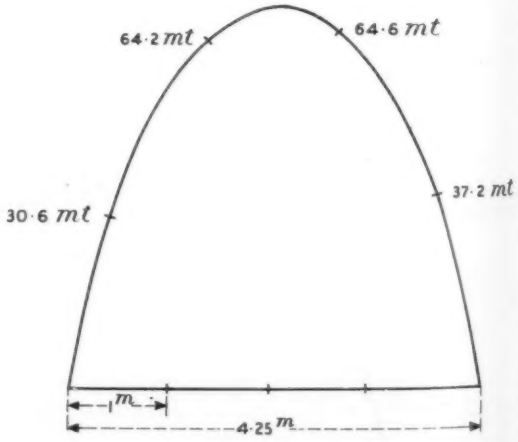


Fig. 16

and

$$E\alpha_C' = \int_o^{l_2} \frac{M}{I}\,dx - E\alpha_B' = 82{\cdot}75 \text{ tons/metre}^2 \ldots (38)$$

with $E = 2{,}000{,}000$ tons/metre^2.

The beam BC is actually not a simply supported beam, but is built in at both ends B and C. The moment M_2^B at the end B is partially transmitted to the beam $BD = l_3$ and to the cylinder AB. We have:

$$M_2^B = M_1^B + M_3^B \ldots\ldots\ldots\ldots (39)$$

At the other end, the moment $M_2^C = M_4^C$ is transmitted to the vertical cylinder $CE = l_4$.

TRANSMISSION OF MOMENTS TO THE FRAME *ABCDEF*

The total angular deflection at the end B of the actual beam BC is the sum total of the elastic deflections produced by the following:

The uniform load p producing an angle α_B' (see equation 37).

The moment M_2^B acting in B producing an angle $M_2^B\alpha_2$ (see Fig. 8).

The moment M_2^C acting in C producing an angle $M_2^C\beta_2$ (see Fig. 8).

On the other hand, the abutment represented by the cylinder AB and the beam BD undergoes an angular distortion $M_2^B\tau_{1-3}$ which should be identical to the angle of the beam BC at point B.

Similarly, at the point C we have to add the angular variations α_C', $M_2^C\gamma_2$ and $M_2^B\beta_2$ and equate their algebraic sum to the angular deflection $M_2^C\tau_4^C$ where $\tau_4^C = \tau^*_{M=1} = \dfrac{3{\cdot}56}{E}$ as calculated previously (equation 17).

The equations of elastic angular deflections at the joints B and C are:

$$\alpha_B' + M_2^B\alpha_2 + M_2^C\beta_2 + M_2^B\tau_{1-3} = 0 \ldots\ldots\ldots (40)$$

$$\alpha_C' + M_2^B\beta_2 + M_2^C\gamma_2 + M_2^C\tau_4^C = 0 \ldots\ldots\ldots (41)$$

which give, solving for M_2^B and M_2^C:

$$M_2^B = \frac{\alpha_B'(\gamma_2 + \tau_4^C) + \alpha_C'\beta_2}{(\alpha_2 + \tau_{1-3})(\gamma_2 + \tau_4^C) - \beta_2^2} \ldots\ldots\ldots (42)$$

$$M_2^C = \frac{-\alpha_C'(\alpha_2 + \tau_{1-3}) + \alpha_B'\beta_2}{(\alpha_2 + \tau_{1-3})(\gamma_2 + \tau_4^C) - \beta_2^2} \ldots\ldots\ldots (43)$$

We calculate that

$$E\alpha_2 = \frac{1}{l_2}\int_{l_2} \frac{(l_2 - x)\,dx}{I_x} - E\beta_2$$

$$= 1{\cdot}503 - 0{\cdot}576 = 0{\cdot}927.$$

We already know $E\beta_2 = 0{\cdot}576$ and $E\gamma_2 = 1{\cdot}306$ and $E\tau_4^C = E\tau^*_{M=1} = +3{\cdot}56$.

It still remains to calculate τ_{1-3}.

The equation $M_2^B = M_1^B + M_3^B$ with $M_1^B = M_2^B\,\mu_{2-1}$ and $M_3^B = M_2^B\,\mu_{2-3}$ where $\mu_{2-1} = \dfrac{\tau_1^{B}{}_{-3}}{\tau_1^B}$ and $\mu_{2-3} = \dfrac{\tau_1^{B}{}_{-3}}{\tau_3^B}$

leads to

$$\tau_{1-3}^B = \frac{1}{\dfrac{1}{\tau_1^B} + \dfrac{1}{\tau_3^B}} \ldots\ldots\ldots\ldots (44)$$

We have already calculated:

$E\tau_3^B = 0{\cdot}50$ tons/metre^2

$E\tau_1^B = E\tau^{***}_{M=1} = 24{\cdot}6$ tons/metre^2 (see equation (16)).

so that finally $E\tau_{1-3}^B = E\tau_{1-3} = 0{\cdot}49$ tons/metre^2.

The solution of equations (42) and (43) gives:

$M_2^B = -46{\cdot}75$ metre-tons.

$M_2^C = -11{\cdot}42$ metre-tons.

$$M_1^B = M_2^B\,\frac{\tau_{1-3}^B}{\tau_1^B} = \frac{0{\cdot}49}{24{\cdot}6}\,M_2^B$$

$$= 0{\cdot}0199 M_2^B = 0{\cdot}93 \text{ metre-tons.}$$

The final value of the moment M_2^C, due to the vertical and the horizontal hydrostatic pressures combined, is therefore:

$$M_2^C = -11{\cdot}42 + 2{\cdot}82 = -8{\cdot}60 \text{ metre-tons.}$$

c. CONSIDERATION OF THE WEIGHT OF THE HORIZONTAL SLAB

In these calculations, the weight of the slab BC itself has been neglected. This should now be considered.

Since the thickness of the generator floor is 2·20 metres, the weight per square metre is $2{\cdot}4 \times 2{\cdot}2 = 5{\cdot}28$ tons/metre^2. In order to ascertain the moments due to this, we can multiply all the moments due to vertical water pressure by the factor $-\dfrac{5{\cdot}28}{20{\cdot}5} = -0{\cdot}258$. The effect of the weight of the slab BD is neglected.

3. Final Table of Moments

Finally, the following table can be constructed:

MOMENTS IN METRE-TONS

Moment due to:	M_C	M_2^B	M_1^B	M_3^B
(i) Horizontal water pressure	2·82	23·2	80·7	57·5
(ii) Vertical water pressure	−11·42	−46·75	−0·93	−45·82
(iii) Weight of slab BC	+2·94	12·05	0·25	11·8
All vertical loads (ii) + (iii)	−8·48	−34·70	−0·68	−34·02

It is easy to verify that the horizontal displacements y of the cylinder AB, due to the moment $M_1^B = -0{\cdot}68$, are negligible.

These moments have been calculated for an angle in the centre $d\varphi = 0{\cdot}222$ corresponding to an arc of 1 *m.* length along the inner cylinder which is the generator support.

4. Special Case when the Joint *B* is Cracked

We now suppose that the slab BD and the vertical cylinder AB are cracked and are unable to transmit moments. The structure to be considered in such a

case is restricted to the slab *BC* and the cylinder *CE*. This may produce conditions which are more severe at point *C*. The moment of inertia of the slab is:

$$I_x = 1{\cdot}73 - 0{\cdot}1975x \ldots\ldots\ldots\ldots (34)$$

The angles $E\alpha_B' = 72{\cdot}95$ tons/metre^2.
$E\alpha_C' = 82{\cdot}75$ tons/metre^2.
$E\gamma_2 = 1{\cdot}306$ tons/metre^2.
are known from previous calculations (equations (37) and (38)). So is the angle $\tau_4{}^C$. If M^* is the moment to be transmitted at the point *C* (Fig. 17) and we neglect the effect of the slab *BD*, the equation of elasticity at point *C* can be written:—

$$E\alpha'_C - M^*E\gamma_2 = E\tau^* = E\tau_4{}^C M^*$$

or giving M^* its algebraic sign:

$$82{\cdot}75 + 1{\cdot}306\,M^* + 3{\cdot}56\,M^* = 0$$

$$\text{which gives: } M^* = \frac{-82{\cdot}75}{4{\cdot}866} = -17 \text{ metre-tons.}$$

A further 2·94 metre-tons have to be deducted if account is taken of the weight of the slab itself.

The angular deflection $E\tau^*$ corresponding to this moment $M^* = -17$ metre-tons is:

$$E\tau^* = -17 \,.\, 3{\cdot}56 = -60{\cdot}6 \text{ tons/metre}^2$$

$$\text{and } \tau^* = \frac{-17 \,.\, 3{\cdot}56}{2 \,.\, 10^6} = \frac{-30{\cdot}3}{10^6}$$

when the effect of the weight of the slab itself is neglected.

It can be verified that the deflection y and the stresses in the generator support *CE* are low, even when this exceptionally unfavourable case ($M^* = -17$ metre-tons) is being considered.

5. Stresses Developed in the Stay Vanes *GH*

In all these calculations we implicity assumed that (Fig. 18) the moment of inertia I^1 of the stay vanes is negligible as compared to the moment of inertia of the generator support. We now want to calculate the stresses produced in the stay vanes by an angular deflection τ^* at their upper end. A moment $M_0{}^*$ at the upper end *G* of the stay vanes produces a moment

$$M_0{}^{**} = M_0{}^* \frac{a^1}{l^1 - a^1}$$

at the lower end *H*. The moment $M_0{}^* = 1$ produces in *G* an angular variation:

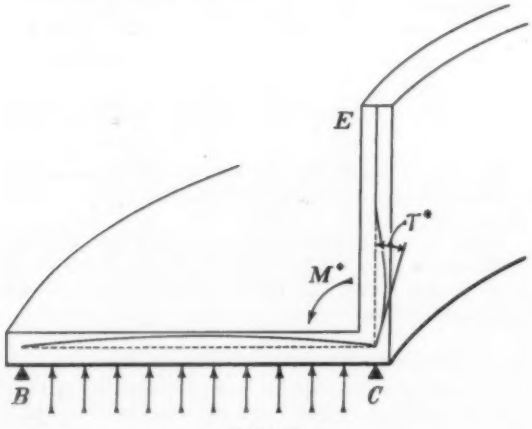


Fig. 17

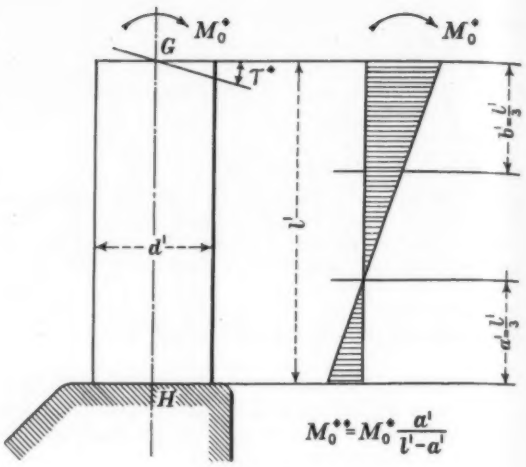


Fig. 18

$$\tau^G = \alpha - \beta\frac{a^1}{l^1 - a^1} = \alpha^G - \beta\left(1 + \frac{a^1}{l^1 - a^1}\right)$$

with $\alpha^G = \dfrac{l^1}{2I^1E}$ and $\beta = \dfrac{l^1}{6I^1E}$, we finally find

$$\tau^G = \frac{l^1}{4I^1E} = \frac{\tau^*}{M_0{}^*}$$

Numerical Example.

$l^1 = 195$ cm.; $b_0 = 152$ cm. (b_0 pitch between stay vane centre lines); $d = 68$ cm. (width of one stay vane); $I^1 = 196{,}000$ cm.^{4} for $b_0 = 152$ cm.; $E = 2{\cdot}2 \,.\, 10^6$ kg./cm.^{2}.

$$\tau^G = \frac{195}{4 \,.\, 196 \,.\, 10^3 \,.\, 2{\cdot}2 \,.\, 10^6} = \frac{1}{8{\cdot}85 \,.\, 10^6 \,.\, 10^3}$$

In the worst case, τ^* is found to be $\tau^* = \dfrac{30{\cdot}3}{10^6}$ and

we have $M_0{}^* = \dfrac{\tau^*}{\tau^G} = \dfrac{30{\cdot}3 \,.\, 8{\cdot}85 \,.\, 10^9}{10^6} = 268{,}000$

kg. cm. = 2·68 metre-tons. Since

$$\frac{M_0{}^*}{I} = \frac{4\tau^*E}{l^1} = \frac{\sigma \text{ max.}}{d^1/2}$$

$$\sigma \text{ max.} = \frac{2Ed^1\tau^*}{l^1} = \frac{M_0{}^*}{2I^1/d^1}$$

$$\sigma \text{ max.} = \frac{2 \,.\, 2{\cdot}2 \,.\, 10^6 \,.\, 68 \,.\, 30{\cdot}3}{195 \,.\, 10^6} = 46{\cdot}5 \text{ kg./cm.}^2$$

The value of $M_0{}^* = 2{\cdot}68$ metre-tons for a spacing $b_0 = 152$ cm.) shows that the stiffness of the stay vanes is not negligible and this adds to the strength of the whole structure. The values of $\tau^* = M_0{}^* \,.\, \tau^6 = \dfrac{30{\cdot}3}{10^6}$ and of σ max. show that there is no danger of overstraining the stay vanes.

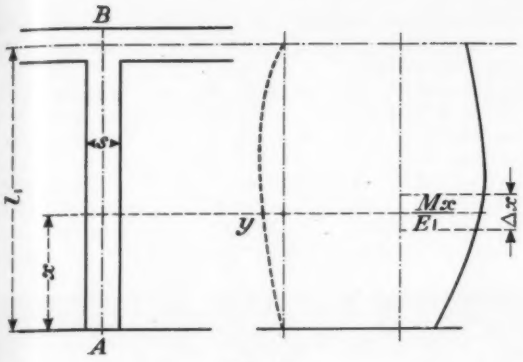


Fig. 19

6. Calculation of the Steel Reinforcement

There is a strong case for making the different elements of the spiral casing—vertical cylindrical outer wall and generator floor—and the generator support, self-supporting under any conditions.

Very severe conditions will occur, if there is a crack between the vertical cylindrical wall *AB* and the slab *BC*. This leads to the conditions already analysed, for which the angle *C* has to be reinforced and the stay vanes carefully calculated.

The cylinder *AB* has to be self-supporting, and the steel loops reinforcing it will be calculated by means of the formula for thin pipes:

$$\text{Tensile stress in steel bars} = \sigma_S = \frac{pR_4}{e}$$

where e is the thickness of the steel which is taken as uniformly distributed over the whole cylindrical height considered.

Furthermore local reinforcement has to be provided. If calculated with a homogeneous material of modulus E, the radial deformation of the cylinder *AB* would be

$$y_m = \frac{R_1^2 p}{E_1 s_1} = \frac{8{\cdot}75^2 \;.\; 20{\cdot}5}{2{\cdot}2 \;.\; 2 \;.\; 10^6 \;.\; 0{\cdot}6} = \frac{5{\cdot}95}{10^4} \text{ metres}$$

The hypothesis of a homogeneous material cannot easily be avoided in the calculations.

This value is far less than the value we obtain when assuming that the steel reinforcement bars would work alone, without any load taken by the concrete. We may assume that the concrete will cause the load to be distributed non-uniformly in the bars and that

$$\frac{y}{y_m}$$

is a measure of the non-uniformity of distribution of the load. The steel reinforcement will therefore have to be increased everywhere by $\frac{y}{y_m} > 1$. The cross section of the steel reinforcement has to be calculated basically with $\sigma_s = \frac{pR_4}{e}$.

THE VERTICAL BARS IN THE CYLINDER *AB*

If *AB* is considered as a vertical beam (Fig. 19) the moments due to its deformation can be calculated direct from the differential equation (29), or alternatively, if the deflections have already been calculated, Mohr's method can be used.

The deflections y of a beam *AB* can be caused by loading the beam with forces

$$\triangle F = \frac{M_x \triangle x}{EI}$$

Knowing the deflections y as a function of x, it is possible to calculate back to the moments M_x and therefore to the vertical reinforcement bars.

Since in our calculations the thickness s is comparatively small, the load will be mainly taken by the horizontal circular reinforcement bars, and the mean deflections y_m will have to be calculated as $y_m = \frac{\sigma_s R_1}{E_s}$ where E_s is the modulus of elasticity of the steel.

If the concrete thickness is greater, the elastic deflections are better given by $y_m = \frac{R_1^2 p}{E_1 s_1}$, since the concrete will take its share of the tensile forces, without being cracked. The amount of vertical reinforcement will therefore depend largely on the thickness s_1 and on the percentage of the load to be taken by the uncracked concrete.

The author would like to thank Mr. N. G. Dennis of the English Electric Co. Ltd., for his help in connection with this article.

Beama Dinner

For the first time since 1938 The British Electrical and Allied Manufacturers' Association held their traditional annual dinner, this taking place at Grosvenor House, London, on January 24. The attendance was a remarkable one and it was understood that about 1,200 people were present. The toast of The Electrical Industry was proposed by Professor E. N. da C. Andrade, F.R.S., Director of the Royal Institution, who spoke of the vast field now covered by the industry and the necessity for a far-seeing organisation to nourish and co-ordinate its activities, particularly in regard to research. To this end he was particularly glad that a Chair of Electrical Engineering had recently been founded at Cambridge.

In responding, Sir George Nelson, the president, referred to the remarkable changes which had been brought about in the world since Faraday's fundamental researches on electro-magnetism. The electrical industry, he stated, now took second place in our all-important exporting industries, the total value of its exports in 1951 amounting to no less than £180 million. The steel problem was a crucial one and he urged that production must be increased to meet the needs of the future. In this matter he said that as the most efficient size for blast furnaces had now been definitely determined, the smaller and less efficient plants should be replaced by this optimum size as soon as practicable. The claim that shortage of scrap was a continuing cause of limited supplies could not be accepted by expanding industries that were depending on an augmented rate of steel production.

To raise the national output in all directions there must be authorisation of extra capital for mechanisation and power plant.

Outdoor Oil Circuit Breaker

A recent addition to the range of switchgear built by Cooke and Ferguson Limited, Openshaw, Manchester, is the type OD2 outdoor oil circuit breaker. The breaker, which is fully short-circuit tested, is suitable for ratings up to 150 MVA at 11 kV (B.S.) and 250 MVA at 15 kV (A.S.A.) with a normal current rating up to 800 A, and is constructed on the horizontal single-break principle, the three phases being situated in one tank. The use of a single arc control device per phase has made it possible to simplify the construction, and the horizontal single-break design is claimed to be almost entirely independent of throw-off magnetic forces, giving an improved performance with the additional advantage of obtaining the maximum accessibility. The sliding contacts are of the compression spring-loaded multi-finger type. They are stated to require negligible maintenance and to be completely free from burning, pitting and seizing. Moving contacts are of round copper section running in accurate guides. Arcing and main contacts are of the compression spring-loaded tulip type, the individual breaker fingers being mounted on a removable plate for easy maintenance. Positive arc extinction is effected by a compensated cross-jet-pot arc-control device, consisting of a resin-impregnated pressboard body fitted with a horn fibre throat.

The tank is of fabricated steel construction fitted with an arc-resisting tank lining, each tank undergoing a routine hydraulic pressure test before assembly. The breaker is fitted with a pebble-filled vent terminated by a non-return valve.

The main-drive assembly is of fabricated steel construction coupled by means of high-pressure resin-impregnated and bonded laminated wood links to a main drive rod of similar material, ensuring a very long creepage path with low electrical stressing over the insulation surface. Two oil dashpots are provided to cushion the drive assembly at the end of the opening stroke.

Oil-filled condenser-type bushings are provided, fitted with first-grade electrical porcelain rainsheds, arcing horns and connecting clamps. The inner condenser bushings consist of a central solid conducting rod on which layers of synthetic-resin-impregnated paper are wound with intermediate layers of foil to ensure a uniform electric field. Flexible copper connections ensure that no stresses are created due to temperature variations. The centre fixing flange is shrunk on to a condenser bushing to form an oil seal, and a porcelain weather shed is clamped to the upper face of the bushing flange, gaskets being interposed between the porcelain and metal surfaces. The circuit breaker is designed to accommodate up to six bushing-type current transformers in turrets accessibly situated in the breaker top plate. The operating mechanism and auxiliary gear are accommodated in a weather-proof housing; the operating mechanism can be of the solenoid, spring (hand-charged), spring (motor-driven), or hand type.

The breaker is complete with outdoor weatherproof supporting framework, constructed from solid iron members, all component joints being of a type to facilitate erecting and dismantling. This frame incorporates a wire-rope winch-pattern tank-handling device operating from a self-locking worm and worm-wheel reduction gear.

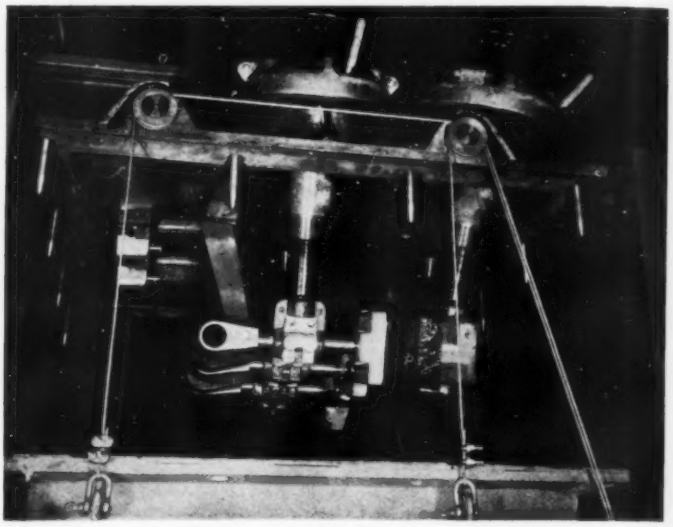
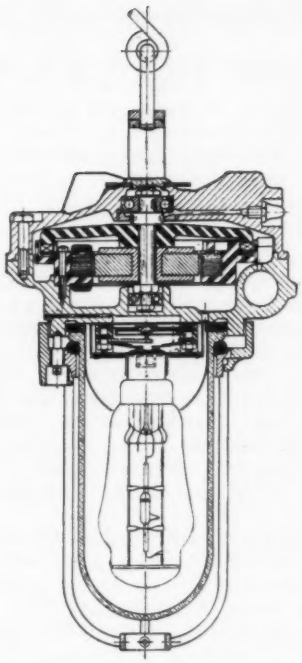


Fig. 1 (left). The Cooke and Ferguson type OD2 outdoor oil circuit breaker
Fig. 2 (above). A view of the interior of the circuit breaker with the case lowered showing the sliding-type arcing and main contacts

Fluorescent Pneumatic Electric Lamps

The pneumatic electric lamp was originally developed to ensure safety in coal mines but has been subsequently applied to oil refineries, tunnelling operations and other situations where there is danger of igniting inflammable gaseous mixtures. In recent



years the usefulness of this equipment has been greatly extended by the development of the fluorescent tube which affords a much greater output of lumens, compared with the filament lamp, for the same consumption of air. But apart from inflammable atmospheres, the lamp has a definite application in ordinary tunnelling where heavy rounds of shots have to be fired by magneto or other types of exploders. Obviously a stray current from normal mains lighting might easily cause a disaster, and moreover there is always some risk of a pocket of inflammable gas being formed by the incomplete combustion of explosives, though we concede this occurrence to be rare.

The pneumatic lamp would appear to afford absolute immunity from accident in either case as it is essentially a self-contained unit and merely needs to be coupled up to a compressed-air supply. Our illustration shows the M.L. lamp manufactured by John Davis & Son (Derby) Limited and consists of a strongly constructed casing which houses a compressed-air turbine and a revolving-field alternator. This alternator is nested inside the turbine wheel, thus reducing the overall dimensions to a minimum. The turbine wheel and rotor are mounted on a short solid spindle running in ball bearings. Air enters through a detachable connection at the side of the lamp, then through a removable air filter to a small reducing valve, which reduces the pressure to approximately 40 lb. per sq. in. before it enters a small rectangular nozzle to impinge on the turbine blading. It then passes through a transfer port moulded in the body of the stator, returning radially outwards through the blading again, to escape finally to atmosphere through a series of holes so proportioned as to maintain a back pressure of 2·3 lb. per sq. in. Suitable arrangements have been provided to employ the escaping air from the exhaust to form an air screen, thereby preventing formation of dust on the outside of the glass.

Each lamp is fitted with an automatic cut-out which consists of a spring-loaded diaphragm, one side of which is in connection with the external atmosphere while the other side is exposed to the excess pressure inside the lamp casing. The diaphragm carries a contact, which normally engages with a fixed contact and short-circuits the generator. When the lamp is working, the excess pressure in the interior holds the contacts open and permits the lamp to light. Failure of this pressure from any cause whatever permits the contacts to close and makes the whole system dead.

The lamp is portable and can be easily moved from one position to another; it is designed for rigorous conditions and requires only occasional attention to the filter and lubrication.

Pneumatic Chain Saw

The accompanying illustration shows a pneumatic chain saw placed on the market by Holman Bros. Ltd., Camborne. It is designed for operation by one man and should be a useful implement for cutting timber for shuttering, tunnelling support, and camp building, for use in clearing reservoir sites and for the many jobs involving timber arising on a hydro-electric scheme. It may be used for vertical or horizontal cuts, and by virtue of a small set-off distance it is possible to cut close to a wall or floor. It will also sink through a wooden floor without the necessity of drilling preliminary holes.

The cutting member is an endless link chain, driven through a sprocket and gearing by a compressed-air vane-type motor. Each link has a cutting tooth formed on its outer edge. The chain surrounds and runs in a channel formed in the guide plate which is roughly of rectangular shape with a rounded end. The width of the cut, which is $\frac{7}{16}$ in., is sufficient to allow the guide plate to follow through. The length of cut is 20 in., and the weight of the machine 39 lb. A single trigger-type control lever operates the saw. The lower side of the cutter chain runs towards the operator and this must always be the cutting side

with the front of the saw frame bearing on the log or timber. A slight rocking motion with light pressure will ensure a clean and speedy cut. The cutting chain can be sharpened after removal from the machine by filing the teeth to the correct angles while held in a vice.

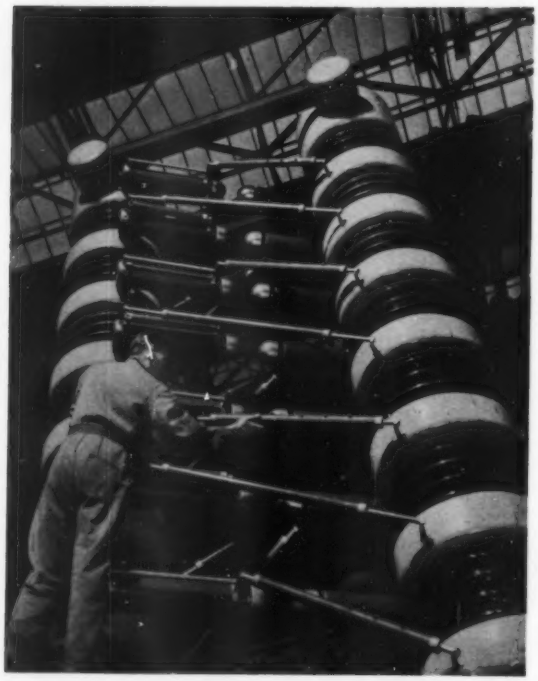
Fina Rust Remover

This product, recently introduced by Fina Petroleum Products Limited, is claimed to dissolve rust, loosen scale and remove tarnish from iron, steel, aluminium, chromium, copper, bronze and nickel but contains no muriatic or sulphuric acid.

If rust is heavy, it is recommended that cleaning be accelerated by removing the excess by wire brush or steel wool, and that any oil or grease present first be removed by white spirit.

D.C. 1,000,000 V Cable-Testing Equipment

An outstanding contract completed by Ferranti Limited during 1951 was a 1,000,000 V d.c. cable-testing equipment for Norway, illustrated herewith. Rectification is on the voltage-doubler principle, the



midpoint of the rectifiers being energised from two 200 kV cascade-connected transformers contained in porcelain housings. This enables the full rating of the rectifiers to be utilised. The arrangement of connections is such that the earthed end may be positive or negative. The connections to the rectifiers and the transformers are so arranged that sections can be connected in parallel to give lower voltages and higher currents. A resistance potentiometer is provided complete with a three-range automatic-range-change milliammeter and direct-reading voltmeter. Provision is made for forced oil circulation through the rectifiers and potentiometer for cooling and insulation.

Two control panels are provided, one for permanent installation in the control gallery of the research laboratory in which the equipment will be used, and the other arranged in portable form incorporating a Ferranti moving-coil regulator for output-voltage variation, this latter panel being used with the d.c. equipment in the field, for testing cables when laid and jointed.

Conveyor Drivehead

The latest belt conveyor driving gear in the M & C range for surface work can transmit 40 h.p. to a belt running at 450 feet per minute, and is suitable for drive by any type of motor or engine.

The driving gear consists of two side cheeks, driving drum, snub pulley, and double speed reduction. A supporting structure can be included, and electric motor, diesel, paraffin or petrol engine or other means of driving. Ball and roller bearings are used throughout.

By choosing a suitable width of driving drum, any width of belt can be taken up to 42 inches. The following standard sizes of motor pulleys give the belt speeds stated, for a driving drum 23½ inches diameter and a motor speed of 1,000 r.p.m.:—

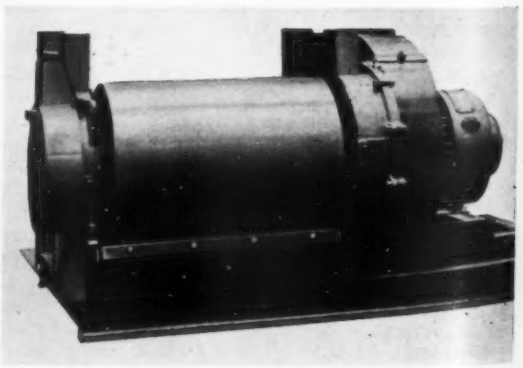
Outside dia. of motor pulley (inches)	Speed of driving drum (r.p.m.)	Speed of belt (ft. per min.)	Maximum allowable h.p.
6¼	24	150	14
8⅞	35	225	20
11	44	280	25
19	136	450	40

The side cheeks are flanged and ribbed to give them great strength without undue weight. They are accurately machined to house the bearings, to carry an oil-tight cover on one side, and for bolting to the underframe. The first speed reduction is by V-ropes. The desired speed is obtained for the conveyor belt by choice in size of the motor pulley.

The second reduction is by straight spur gearing, the teeth of which are machine-cut and heat-treated. The gear runs in a dust-proof and oil-tight chamber formed in one of the two side cheeks.

The drum that drives the conveyor belt is 23½ inches in diameter and widths are available for belts from 24 inches to 42 inches wide. The arc of contact of the belt on the drum is increased by the snub pulley, which raises the return belt.

Without structure or motor, the driving gear weighs 18 to 22 cwt., according to the width of the belt.



Abstracts from the World Technical Press

Lavey Hydro-Electric Station

The proceedings of the "Société Suisse des Ingénieurs et Architectes" at their 62nd general meeting, held in Lausanne on October 5, 6 and 7, 1951, fill the whole of a double issue of the "Bulletin Technique de la Suisse Romande," and are almost exclusively devoted to a comprehensive survey of the Lavey development scheme. As the mechanical and electrical features have been dealt with in last year's February issue of WATER POWER (Vol. 3, No. 2, pp. 45 to 53) the following abstract is restricted to the civil-engineering aspects of this important project.

Fig. 1 shows the general plan and longitudinal section of the installation. The dam and intake are situated immediately upstream of the Rhône elbow, tests having proved that this was the most favourable site. The diversion tunnel follows a track dictated by geological conditions down to the surge chamber whence the three penstocks lead to the power house. The draught-tubes of the turbines connect with underground conduits and ultimately discharge into the Rhône at the mouth of the Courset river.

The dam has three double sluice gates, each 13·0 m. in width, which can be lifted or lowered simultaneously or independently of each other so as to direct the flow above or under the gates. If necessary an unimpeded flow is ensured by lifting the gates right to the extremity of their upward travel. Actually, the Swiss Federal Authority require that two out of the three gates should prove adequate to cope with the maximum flood discharge, under the assumption that the third gate has been jammed in its fully closed position. A guide wall extending upstream from the right bank abutment pier creates a current which prevents floating materials from reaching the middle and left-bank gates; these two gates only are open in normal working of the power house. The dam gates discharge into a stilling pool provided with a counterslope apron.

The water intake proper consists of two inlets 4 m. high and 30 m. wide, each divided by a wall in two halves and connecting with the diversion tunnel through conduits gradually decreasing in cross section. The height of the intake sill in relation to the floor has been determined so as to prevent floating materials from entering the diversion, and, at the same time, to evacuate these materials automatically.

Taking into account the lower cost of a single diversion tunnel, and the complications involved in driving a second tunnel while the first was in operation, the solution finally adopted was that of a single tunnel of relatively small diameter (7·75 m.). In point of fact, with this diameter, head losses in the first period of operation did not exceed 1·80 m. at the maximum discharge of 132 cu. m. per sec. and did not increase beyond 4·15 m. at the installed maximum discharge of 200 cu. m. per sec. This increase is justified because the highest head losses occur during the summer months, when the value of energy is smaller, while the considerably more valuable production of the winter months is not appreciably affected by the re-

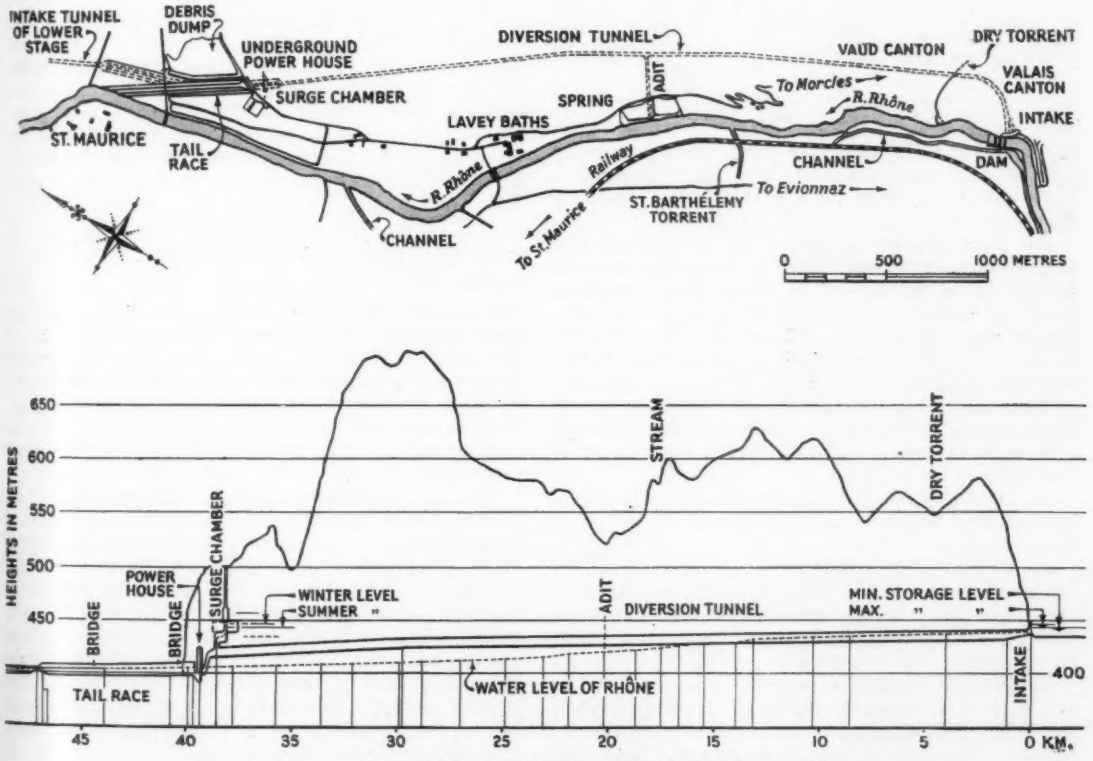


Fig. 1. Layout plan and longitudinal profile of the Lavey scheme

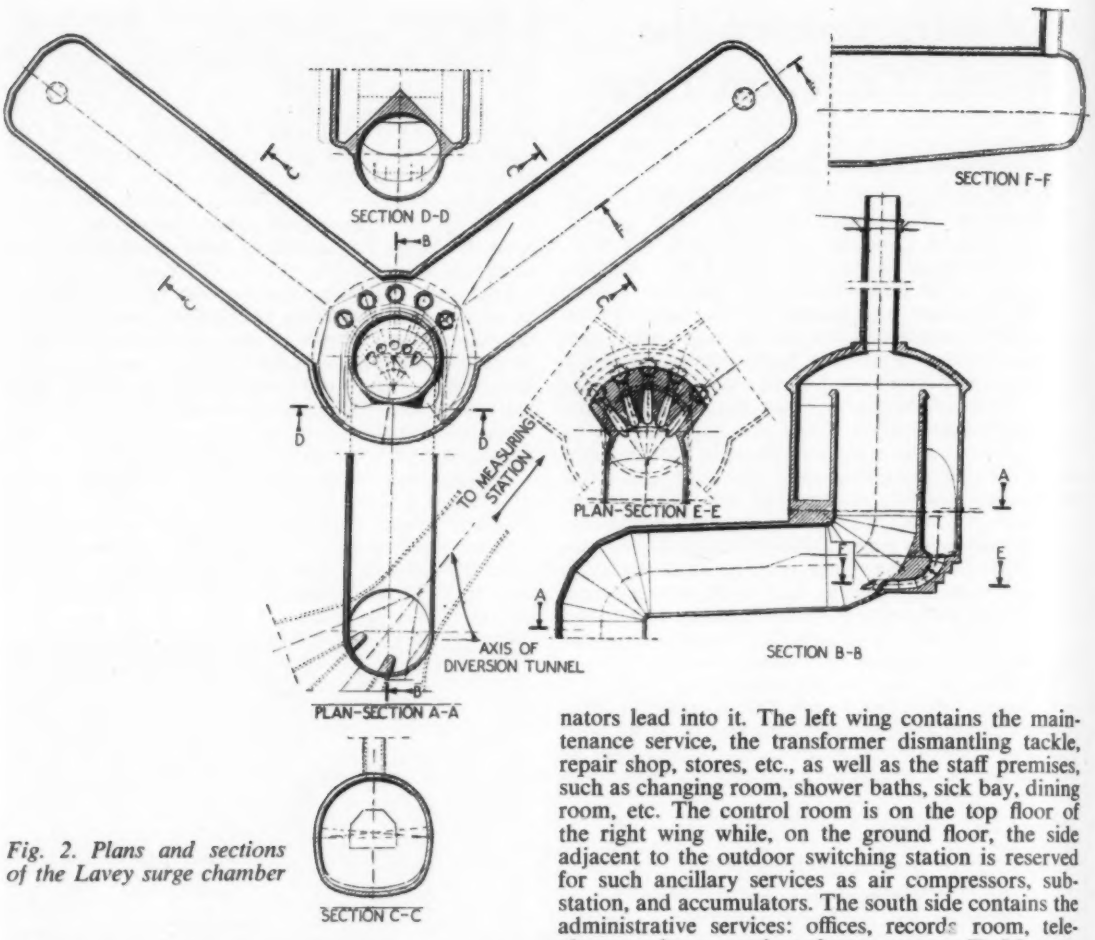


Fig. 2. Plans and sections of the Lavey surge chamber

duction of the diameter. The particularly interesting type of sand trap chosen for the Lavey installation is described in detail in the May, 1951, issue of WATER POWER (Vol. 3, No. 5, p. 198).

The surge chamber is sited at the downstream end of the diversion tunnel. After a wide range of tests carried out in the laboratory of the Lausanne High Technical School under the supervision of Professors Stucky and Bonnard the differential surge chamber shown in Fig. 2 was adopted as most likely to give the most favourable results as to mass oscillations, protection of the tunnel against water-hammer, service requirements, etc. The Lavey surge chamber was built entirely in the rock, and involved a huge work of excavation.

At the top end of the penstocks butterfly valves in the valve chamber permit the flow to be cut off when required

As to the tailrace, backwater curves obtained by calculation enabled the water level at the outlet of the power house to be determined in function of the Rhône discharge and of the level at the point of return to the river.

The surface building is such an imposing structure that it is often taken for the power house proper; in fact, each of its three sections serves a clearly defined purpose. The central section shelters the 6,000 and 10,000 V electric equipment; the cables of the alternators lead into it. The left wing contains the maintenance service, the transformer dismantling tackle, repair shop, stores, etc., as well as the staff premises, such as changing room, shower baths, sick bay, dining room, etc. The control room is on the top floor of the right wing while, on the ground floor, the side adjacent to the outdoor switching station is reserved for such ancillary services as air compressors, substation, and accumulators. The south side contains the administrative services: offices, records room, telephone exchange, and conference room. (P. Meystre, Director of the Lausanne Corporation's Electricity Service, *Bulletin Technique de la Suisse Romande*, Vol. 77, Nos. 19/20, 4.10.51, p. 251, 43 pp., 65 ff.)

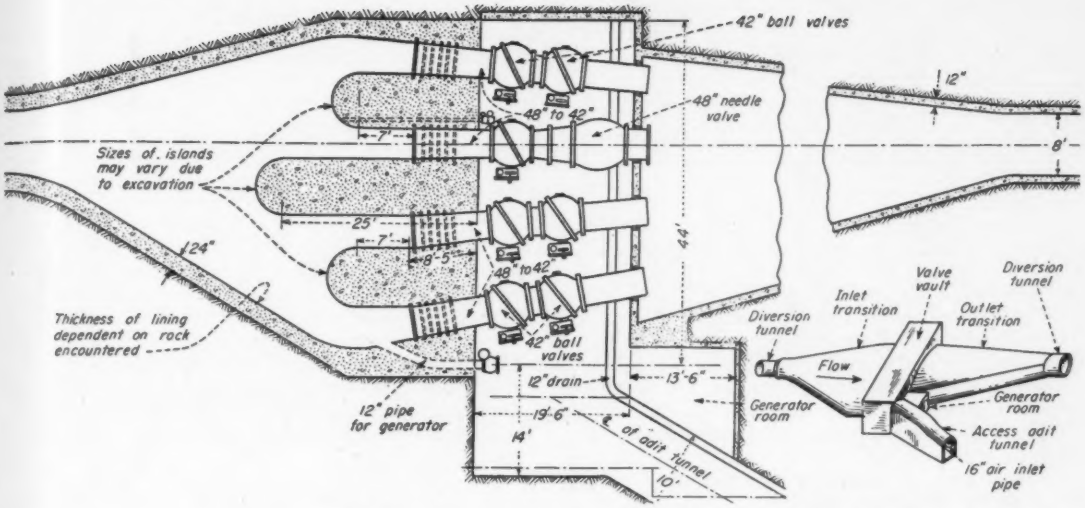
Underground Controls at South Boulder Creek Dam

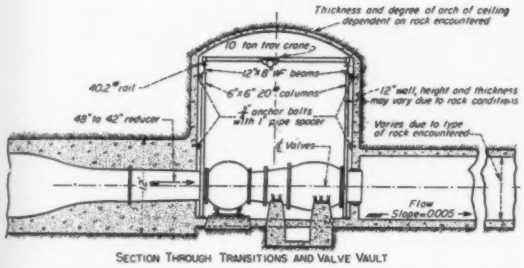
Colorado's highest dam, now under construction on South Boulder Creek, about 35 miles north-west of Denver, will have its main outlet valves protected against bomb attack. They will be in a subterranean chamber 58 × 19½ ft. in plan, located in the left abutment of the dam, which affords the vault a vertical rock cover of 225 ft. and 100 ft. of horizontal protection.

The dam is of the gravity type and will be 340 ft. from the base of the foundation to the crest, with a long-radius arch (1,740 ft.) to fit the topography of the site. Length of crest will be 1,022 ft.

Four 42 in. outlets will be set along the 10 ft. diameter, 800 ft. long diversion outlet tunnel, each outlet being controlled by one operating and one reserve valve. The lower outlet must be able to pass the natural flow of South Boulder Creek up to 1,200 cusecs; another outlet about 160 ft. higher will provide the supply to the 7,875 kW power plant to be built in connection with the reservoir.

In addition to protection from air attack, it is




Thickness and degree of arch of ceiling dependent on rock encountered
10 ton trav. crane
40.2" rail
12"x8" WF beams
6"x6" 20" columns
48" to 42" reducer
1" anchor bolts with 1" pipe spacer
12" wall, height and thickness may vary due to rock conditions
Varies due to type of rock encountered
Valves
Flow
Slope=.0005

SECTION THROUGH TRANSITIONS AND VALVE VAULT

Plan and section of valve vault

claimed that the control vault, as shown in plan and section in the appended diagrams, will protect the valves against freezing in extremely cold weather without the help of any heating arrangement. (*Engineering News-Record*, Vol. 147, No. 16, 18.10.1951, p. 47, 2 pp., 2 ff.)

Regulating Overflow by Means of Syphons

In this article syphons are advocated as a means of regulation for the overflow discharge in weirs and spillways since they can be built at a fraction of the cost of really reliable spillways, and eliminate the maintenance work necessary in the case of gates. To ensure an efficient overflow regulation, a syphon must fulfil the following conditions: reliable and quick priming, absorption of the wave resulting from the shutdown of a unit, adjustment of its discharge to the discharge cut off by the turbines, and full protection against obstruction by floating solid matter or ice.

Suggestions are made as to how these conditions can be fulfilled without the help of moving mechanical parts. The measurements of the various parts of the syphon (upstream and downstream leg, air inlet, and priming lip) must be determined in such a way as to ensure the adjustment of the discharge as a function of time to the difference between the cut-off discharge and that absorbed by the positive wave resulting from the lowering of the water level. In a system consisting of a battery of syphons, unpriming is avoided and the stability of the system at partial discharge is ensured by staggering the priming levels of the various syphons. The same result can be obtained in the case of a single syphon by using air inlets of improved design, but this solution cannot be applied to every type of syphon. The appliance patented by the Neyrpic concern appears to meet all requirements, and has the advantage of operating, at the same time, as an auxiliary priming ejector.

As a rule a grating at the intake will provide against obstruction of the syphon by floating solid matter, obstruction of the priming system is a more serious problem, which can, however, be easily solved. In the case of massive obstruction, imperfect partialisation can be tolerated provided the water in the syphon does not exceed the rated level. Obstruction by ice is very infrequent in France; it is most likely to occur

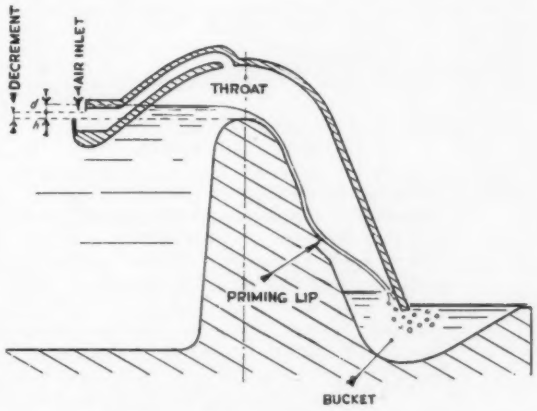


Fig. 1. Usual type of syphon

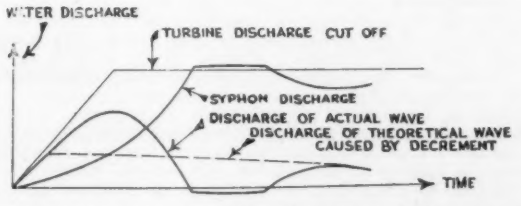


Fig. 2. Ideal law governing the priming of syphons

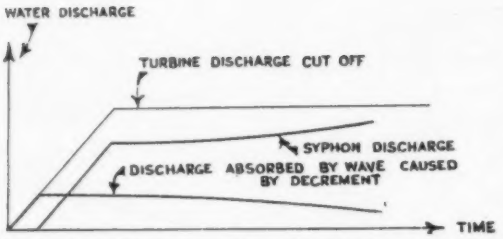


Fig. 3. Actual law governing the priming of syphons

in the bucket of the downstream leg but can be checked by means of a duct conveying water direct from the bottom of the forebay to the downstream leg. Freezing of the upstream leg can occur only in connection with reservoirs which have a very quiet water surface, and never happens suddenly so that the staff of the power plant can hardly be taken by surprise.

With a view to obtaining as economical a design as possible the author advises the reduction of the width of the battery of syphons, so as to reach the highest possible discharge per metre.

In spite of the fact that syphons have never been very popular in France they have been adopted lately in several instances, particularly in connection with plants to be enlarged or reconstructed. Examples given of two such installations certainly tend to prove that syphons are able to ensure the safe operation of the plant. (M. Blanchet, "Mémoires et Travaux de la Société Hydrotechnique de France," Vol. II, 1951, p. 194, and *La Houille Blanche*, Vol. 6, No. B, October 1951, p. 648, 7 pp., 12 ff.)

Water Power in Africa. In connection with this article published in our February issue, a Swiss correspondent, Mr. Rene P. Chauvet, has pointed out that the estimated capacity of a quarter of a million horsepower appears to omit certain developments in French North Africa and the Belgian Congo which would bring up the total capacity to at least 364.000 h.p. If installations in Reunion, Mauritius and Madagascar are included the total capacity approaches half a million horsepower. Both the editor and the author of the article are grateful to have this omission pointed out.

The Shire Valley Project. We are indebted to Eng. Castro Cabrita, of Lisbon, for kindly pointing out that the sketch map we published in connection with the Shire Valley Project on page 410 of our November 1951 issue, is in error, and that the territory marked as Southern Nyasaland should really have been Mozambique.

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

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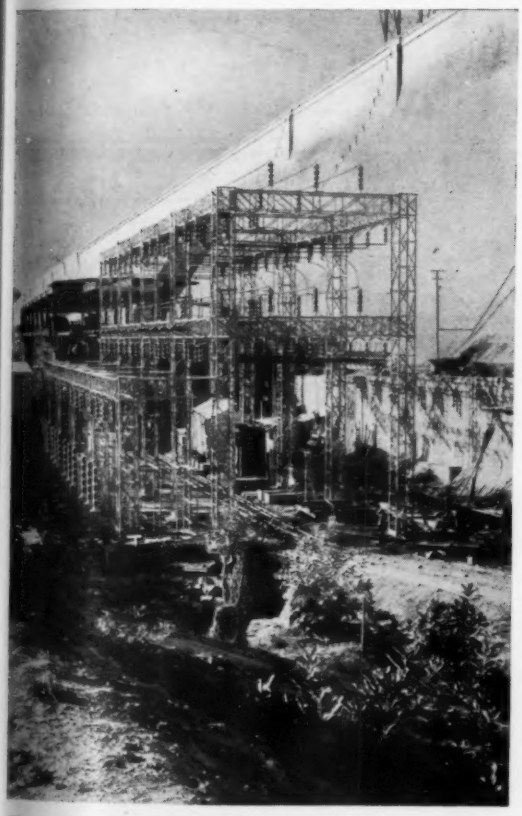

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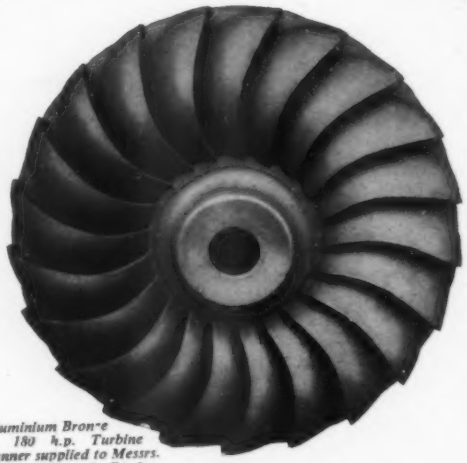

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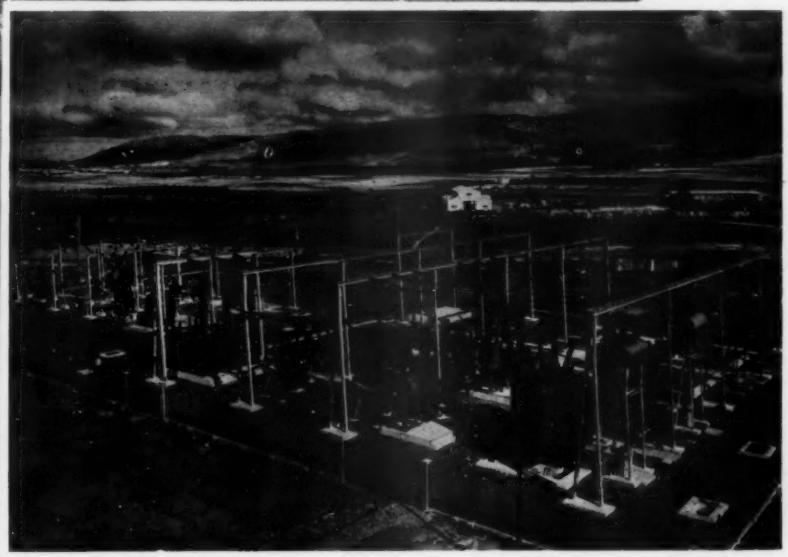

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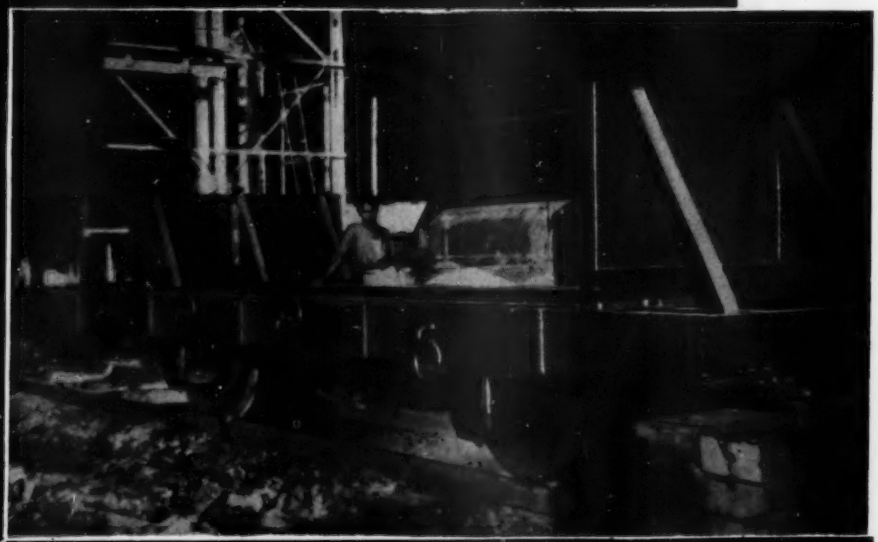

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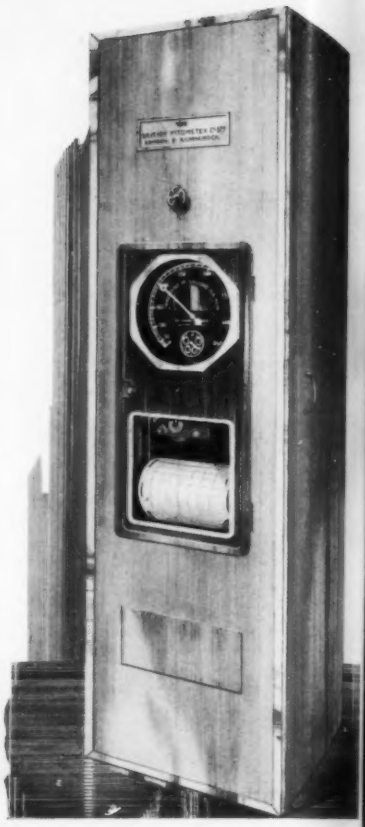

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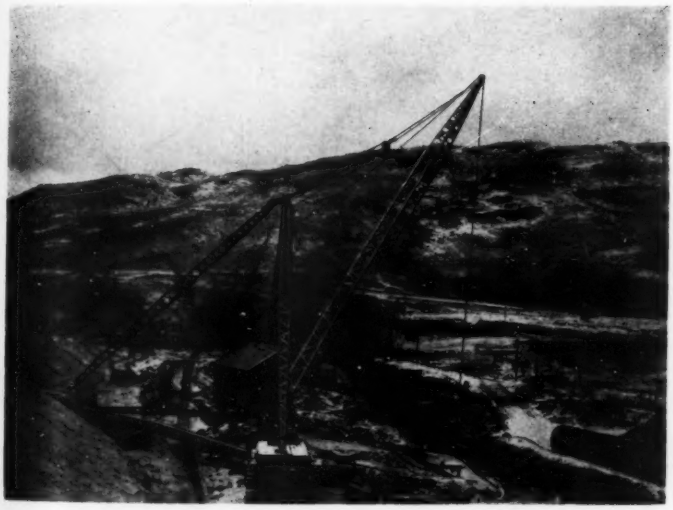

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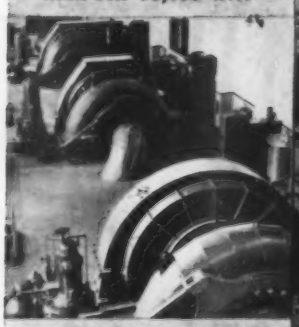

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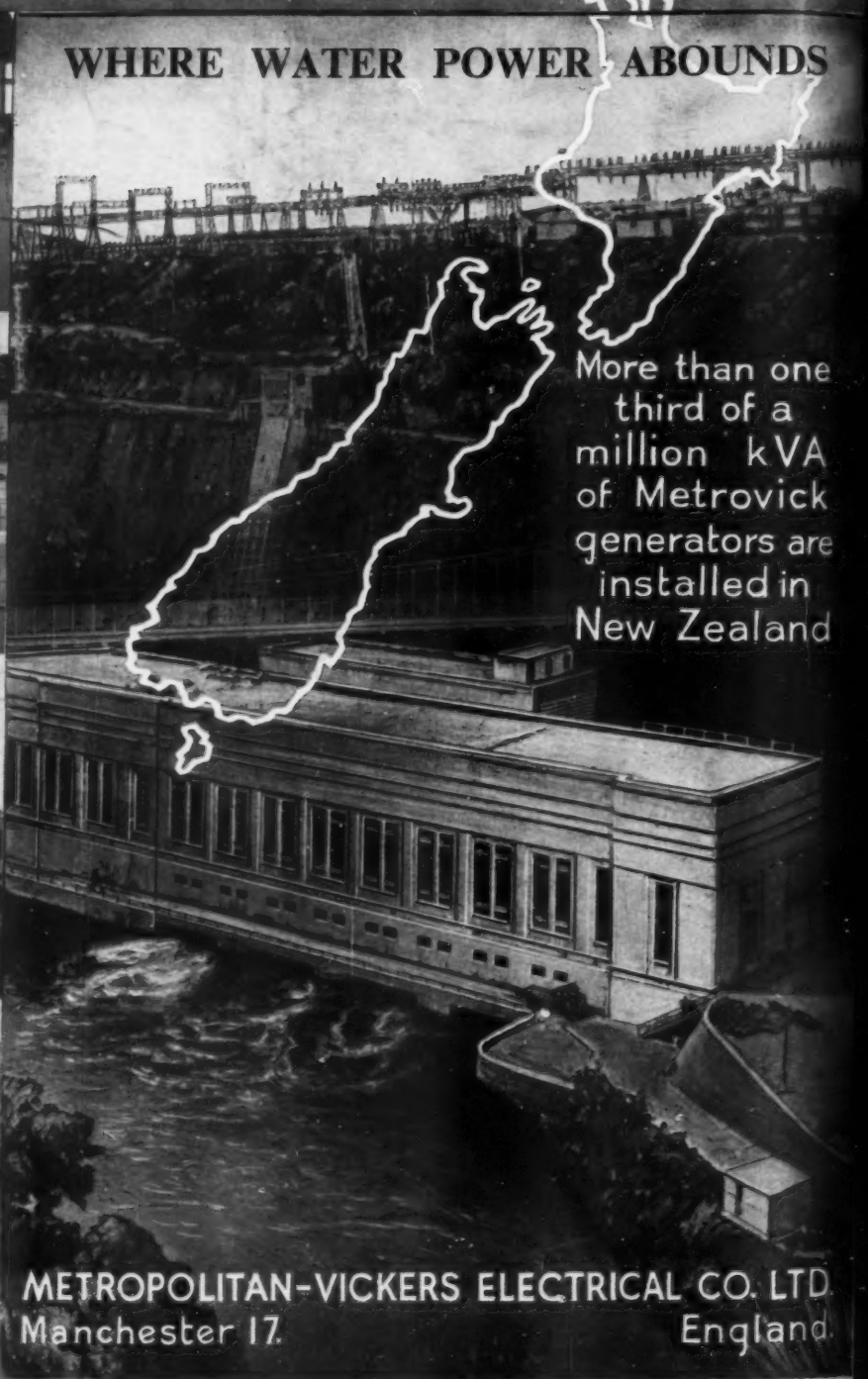

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